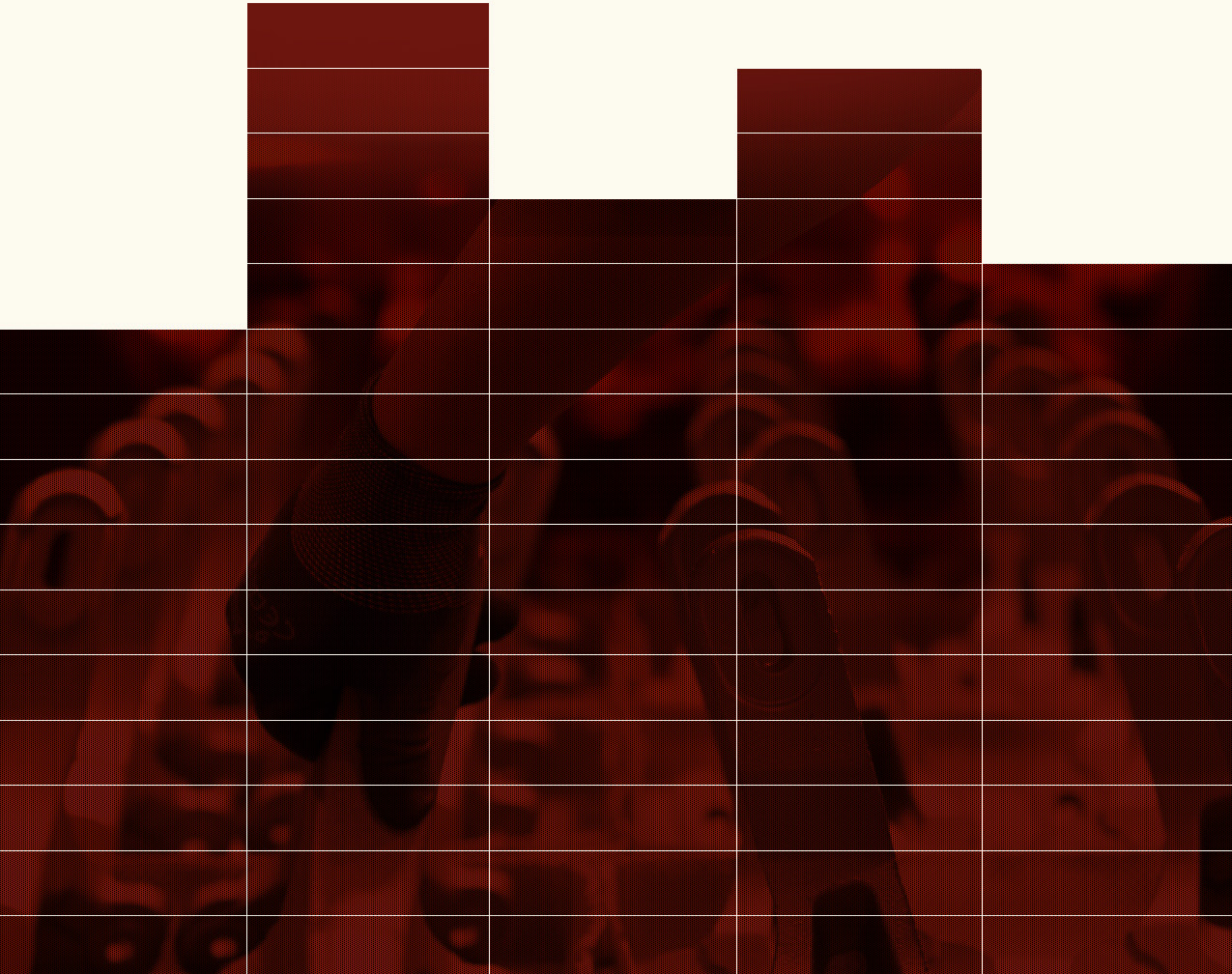
Risk Management in Heat Treatment



Manufacturers depend on delivering quality parts consistently. Ensuring part integrity on an industrial scale means creating and adhering to quality control measures throughout the production process.

While heat treating is just one of the many steps in your products' journey to sale, the process puts great stress on parts. The right heat treater recognizes its important role maintaining part integrity and should take some of the burden of assuring quality processes.

We've put together this guide to introduce three unique heat treatment risks and highlight risk management processes we undertake to ensure your products meet your standards and are fit for whatever comes next.

Cracking risk

Metal parts are subjected to intense stresses before their final desired hardness is achieved. While the science behind hardening is complicated, customers' demands are simple: Improve parts without destroying them.

There are many reasons cracks can occur during treatment. That's why part design is so critical to reducing the risk. Understanding how design can influence cracking risk and monitoring parts for design characteristics that could promote cracks are the most effective ways to prevent failure.

The principles outlined below apply to any type of part, but tool and die components face the greatest risks.

It's all about cross section

A part's shape can make or (literally) break it during heat treating. Hardening first requires temperatures high enough to cause a transformation in the metal's crystal structure. During the cooling that follows, the part surface cools and hardens more quickly than the core. As the core hardens, it expands, putting pressure on the part surface.

Drastic changes in a part's cross section present cracking risks because the stress focuses around points where these sudden changes occur. Consider these common design characteristics as part of your risk management scheme:

Thin webs of metal between much larger masses pose a significant cracking risk due to abrupt changes in the part's cross section. During heating, the thinner portion will reach the desired treatment temperature much faster than the larger parts. During cooling, it will cool and transform much more quickly. These stress differentials all but assure the part will crack. The best way to avoid this is to design parts without thin webs.

Another example of a thin web is the area of a stamping that lies between two holes machined closely together. To avoid cracks, heat treaters can pack the holes with furnace insulation, diminishing the cracking risk by making parts with holes in them behave as though they had none.

Knife edges are thin, sharp slivers of metal often found in holes in a die when machining doesn't punch completely through it. Avoid this by inspecting dies thoroughly before heat treating and either rejecting or reworking them when knife edges are detected.

Lack of radii refers to cross section transitions that are not smooth or parts that contain corners that are not sufficiently rounded. Parts designed with a lack of radii are at greater risk of cracking. Designing parts that gradually taper from one size to another and that feature well-rounded corners reduces cracking risk as heat treatment stresses are applied more uniformly across them.

Under special conditions, using dummy blocks in notches, gaps or corners of dies acts in a similar way to furnace insulation, diminishing the cracking risk by making parts temporarily more uniform during heat treatment.

Welding prior to heat treatment can set the stage for cracking. The intense heat of welding puts significant local stress on an area of a part surrounded by parts not under stress. Also, if weld puddles aren't smoothed over via machining, the rough shape further concentrates stress, increasing the chance for a crack to form.

A common misconception is that only the areas of parts that display the design faults listed above will be affected by cracking. However, while these areas may represent only small portions of a part, the cracks that begin there are likely to rip through an entire piece.

Monitoring and communication

While understanding how design characteristics influence cracking risk, part owners, engineers and heat treaters must actively manage those risks from design through production and final treatment.

Some designs are just too risky. While metallurgists will notice this and alert the proper parties, part owners can save time and expense by learning how design influences cracking risk before their materials ever reach a furnace.

Heat treat scale

Scale formation is another risk faced by parts during heat treatment. The dark brown or black flaky material is often observed on the surface of a part when exposed to high heat.

Often, parts require additional machining after they're heat treated, and if heat treat scale isn't removed, it can flake off during machining. That can wear out or damage tools or increase the risk of surface defects on the finished part.

Heat treat scale can be removed or prevented, but manufacturers and heat treaters face some trade-offs when determining which makes the most sense.

What causes heat treat scale?

Scale is an iron-rich film that can form on a part once it reaches high temperatures in heat treatment or manufacturing settings where the atmosphere is not controlled.

There's no fixed temperature associated with scale formation because it's very dependent on the elements making up a part. For instance, "cleaner" steels with low carbon content and low or no alloys scale more easily and at lower temperatures.

High-carbon, high-alloy steels are more resistant to scale, and much higher temperatures are required before it forms.

Heat treat scale removal

Manufacturers and heat treaters each have their preferred scale removal methods. Common methods include "pickling" a part in oil, washing it in scale removal chemicals, electronic removal (via a process that's essentially the opposite of electroplating) and mechanical removal.

Heat treaters typically prefer mechanical removal via blasting. Chemical removal requires the use of dangerous materials that would force compliance with added environmental regulations.

One of the trade-offs in the scale removal vs. prevention debate surrounds what will happen next to a part. For example, forgings often are machined after through hardening. It's cheaper to heat treat in a non-atmosphere controlled furnace where scale will form and then remove the scale afterward because further machining will occur. That's opposed to treating in a controlled-atmosphere furnace where scale won't form but which is more expensive to run.

Similarly, heat treat scale removal can be recommended for larger batches because it's cheaper to heat treat in larger, non-atmosphere controlled furnaces and then remove scale as opposed to running multiple smaller batches through atmosphere-controlled equipment.

Heat treat scale prevention

There are some instances, however, when heat treat scale prevention is recommended over removal.

For example, tool steel and stainless steel parts are often best treated in vacuum furnaces that remove atmosphere from the chamber. With no atmosphere to react to, scale won't form. The parts do not experience decarburization and do not form cases, such as in case hardening.

A manufacturer could request that parts be treated in vacuum furnaces which suck atmosphere out of the chamber or in integral quench furnaces designed to eliminate oxygen in the atmosphere to prevent scale formation, but those processes are more expensive. It can sometimes be cheaper to treat in furnaces without atmospheric control and then remove the scale afterward. Raw castings and forges, for example, are often allowed to scale during normalizing because they'll be heavily machined after treatment anyway.

Plan ahead

Remember that scale formation represents an actual loss of material on a part. If you're concerned that your specs don't account for this loss, speak with your engineers about designing with scale removal in mind and whether it's feasible to design with more scale-resistant materials.

Heat treat scale is a fact of life in the industry. Managing it comes down to knowing what your parts are made of, knowing which heat treatments are most appropriate and making an economic decision.

Decarburization in steel

Another heat treatment risk is decarburization, which can weaken steel parts and put them at greater risk of failure during their service. There's even an industry standard —ASTM E1077—dedicated to decarburization depth measurement.

Preventing decarburization in steel requires metallurgists and their customers to pay attention to the details.

What happens during decarburization?

Decarburization occurs during the interaction between the carbon atoms in steel and the atmosphere of an endothermic atmosphere furnace. It's essentially the opposite of carburization—carbon is drawn out of ferrous material rather than put into it.

It happens when carbon content inside the furnace is not properly controlled. When the conditions aren't right, carbon atoms in a steel part diffuse outward through its surface. Decarburization can occur during manufacturing prior to heat treatment and also as a result of heat treatment processes.

Parts where decarburization is often observed prior to heat treatment include investment casting parts, forgings and castings and medium-carbon steels derived from hot-rolled barstock.

Investment castings can have significant decarburization stemming from sub-par conditions in foundry equipment, but this can be reversed during heat treatment with a carbon restoration.

For forgings, castings and barstock, decarburization can either be machined off or fixed via carbon restoration.

What can go wrong?

Just as adding carbon to steel makes it stronger, removing it makes it weaker.

The surface of a part is most affected during decarburization. Because carbon is drawn out through the surface, the result is a part with less carbon content near the surface compared to the core.

With less carbon at the surface, a part becomes less resistant to stress. Parts that encounter extreme rotating or alternating forces —structural bolts, for example— are prone to fail if decarburization occurs. Decarburization also presents added quench cracking risks for parts made of more hardenable alloys.

Usually, decarburization during heat treatment occurs when carbon is not adequately controlled in the furnace. Carbon control isn't easy, so it's critical that furnaces are always monitored and regularly calibrated to ensure peak performance.

Decarburization test methods

Because decarburization saps a part of its strength, metallurgists can measure that loss using some of the same hardness testing methods used to measure the part's surface hardness.

For example, the depth and extent of decarburization can be determined by using a Knoop microhardness test. Hardness is measured at greater and greater depths perpendicular to the part surface until a constant hardness is observed.

Decarburization depth measurement can also be conducted with metallographs. Metallurgists use these powerful microscopes to observe and measure how deep from the surface carbon loss has occurred.

Preventing decarburization

In some cases, the damage done by decarburization can be undone via a carbon restore. This involves putting a part back into the furnace with the atmosphere calibrated to replace the carbon that was previously drawn out.

But it's easier and less costly to prevent decarburization, and both heat treaters and their customers can work together to see it through.

For manufacturers, it's important to know the parts at high risk of decarburization. Investment castings and, to a lesser extent, hot-rolled bar stock parts often have decarburization present prior to heat treatment. Millstock present on these parts prior to heat treatment should be machined off to help avoid decarburization.

Then, the burden shifts to heat treaters. Ensuring correct calibration and control of heat treating equipment is critical.

Partners in risk management

Maintaining part quality throughout a supply chain is hard work. If you choose to outsource your heat treating needs, insist on a partner who understands its role and uses it as an opportunity to assure quality.

Paulo combines top-of-the-line heat treatment equipment and leading expertise with a computerized process control system we built ourselves. The system keeps our experts supplied with real-time metrics we analyze to ensure every treatment we complete is done with care, quality and precision.

Contact us if you'd like to talk more about our approach to risk management in heat treatment. And if you're ready to see some numbers ahead of your next project, request a quote now.