

NITREG® POTENTIAL-CONTROLLED NITRIDING

THE MOST ADVANCED SURFACE HARDENING ALTERNATIVE



WHAT IS NITRIDING?

General Description

A good technical “dictionary” definition of nitriding would run more or less as follows:

NITRIDING – a surface (or case) hardening process whereby nitrogen is diffused into the surface of components made of a ferrous alloy, by exposing the metal to a nitrogen carrying medium, such as gaseous ammonia, cyanide containing salts, or ionized nitrogen gas (plasma), while maintaining a suitable temperature, usually in the 450 °C to 600 °C (850 °F to 1100 °F) range. The hardening effect is produced by nitrogen forming hard nitrides with iron, chromium, aluminum, and certain other elements in the alloy.

Since the early days of nitriding, in the 1920’s, various techniques of utilizing the aforementioned media have evolved. These three distinct groups are generally referred to as gas, salt and ion (or plasma) nitriding. The proponents of their selected favorites have promoted their respective advantages without adequately explaining the differences or similarities between them. This is what we shall endeavor to do here.

WHY NITRIDING?

Reasons to Use a Nitriding Process

Components are nitrided for a variety of reasons, but primarily to:

- increase the surface hardness, thus enhancing their wear and fatigue resistance,
- corrosion protection,
- appearance.

NITRIDING METHODS

Brief Description of Nitriding Technologies

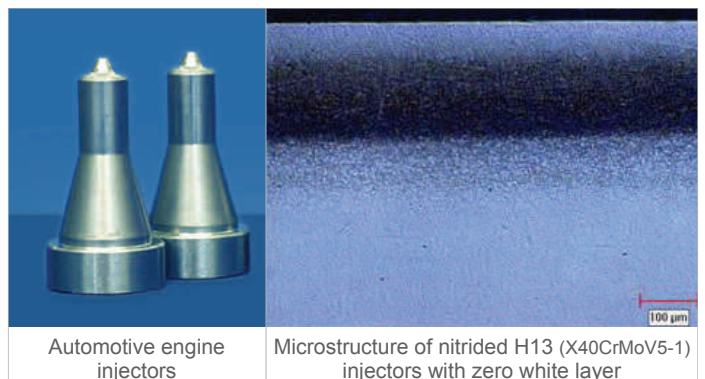
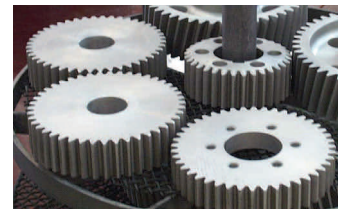
From a purely theoretical point of view all three methods are capable of producing a desirable hardened case. With proper process control a whole spectrum of case properties may be achieved. However, difficulties develop very quickly when we look at a practical side of nitriding. Generation of the required nascent nitrogen, maintaining its proper supply near the surface of the metal, proper control of process parameters in steady state, as well as between the various stages of the process, in dynamically changing conditions, are challenges that few have been able to master. In addition one must deal with economic and environmental aspects of running a nitriding installation. In general terms the three methods compare as follows.

Salt Bath – a quick and easy process, suitable for crude components, but expensive to operate and environmentally hazardous; additional post-processing cleaning required. Melted cyanide and cyanate containing salts are the source of nascent nitrogen. The main advantage is short heating times as cold components are lowered into a molten salt, thus heating the work piece rapidly.

Plasma (Ion) – versatile and capable of producing good results on simple components, but requiring very skilled operators; significant risk of local over-temperature effects; deep cavities and bores virtually impossible to nitride; easy masking; environmentally friendly; suitable for specialized applications. Nascent nitrogen is obtained by ionizing nitrogen gas in an electrically charged field. This process is used by Nitrex and it is described in a companion brochure.



Gas – the most versatile and economically viable if controlled properly; old or poorly designed equipment subject to ammonia leaks, lack of uniformity or simply plagued by the absence of knowledge how to operate such equipment correctly, aspects which have occasionally given all of nitriding an undeserved, poor reputation; components will nitride properly in any configuration even when lightly touching, thus the capacity of a gas nitriding vessel of a certain size is much greater than that of a plasma (ion) furnace. The source of nascent nitrogen is ammonia gas. This process has served Nitrex as a springboard to the development of the most versatile nitriding technology available today – **the potential-controlled nitriding.**



Automotive engine injectors

Microstructure of nitrided H13 (X40CrMoV5-1) injectors with zero white layer

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WHAT IS NITRIDING POTENTIAL?

Explanation of the Concept of Nitriding Potential

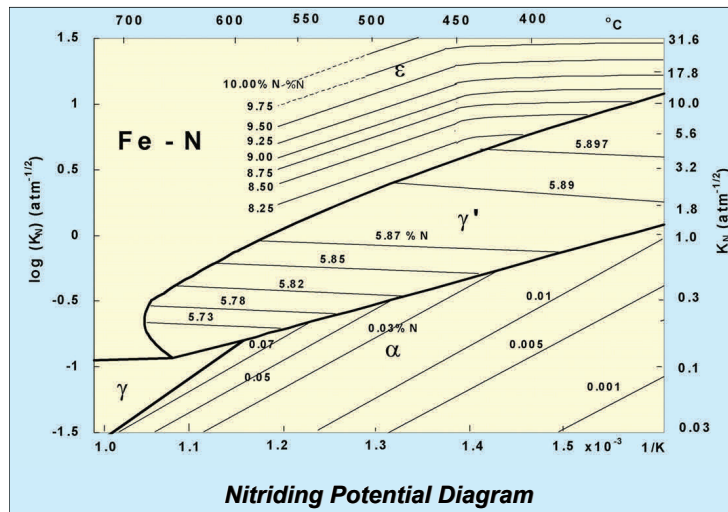
The most fundamental thermodynamic principle involved in the process of nitriding is that of maintaining a proper concentration of nascent nitrogen near the surface of the component. Traditional methods of gas nitriding, with their wide ranges of allowable dissociation rates, are not refined enough to always produce desirable results. In fact most of the users of nitriding equipment do not even realize that it is technically possible to obtain better results consistently.

A concept, known to science but hitherto hardly ever used, is that of Nitriding Potential ("K_N"). K_N is a mathematical quantity which expresses the level of nascent nitrogen available for diffusion into the surface layers of steel, while at the same time being directly correlated to the nitrogen concentration in ε and γ' phases of the case. Even though the formula for K_N is fairly easy to understand (ratio of partial pressures of ammonia, to that of hydrogen to the power of 3/2) it has been very difficult to apply in practice, as no suitable sensors were available to most users, and there was an almost total lack of knowledge in the industry as to how to conduct a nitriding process properly.

Furthermore, pure ammonia atmospheres used most frequently in traditional nitriding are very difficult to control precisely. Control attempted through an increase in the ammonia dissociation rate is only partially effective. Higher dissociation rates are conducive to the generation of large amounts of recombined molecular nitrogen, which not only does not diffuse into the steel surface, but it also impedes the absorption of nascent nitrogen. Conversely, a relatively small decrease in the dissociation rate may produce nitrogen over-saturation of the case and lead to a brittle surface layer.

Well intended but poorly applied improvements whereby diluting gases, such as molecular nitrogen or hydrogen are mixed with the ammonia, make the task of controlling

the process by dissociation rates even more perilous. The apparent dissociation rate is encumbered with an increasing margin of error due to changes in volumetric ratios of the constituents, and the expansion of the dissociating ammonia. The ability to quantify the Nitriding Potential existing in the furnace, however, permits the user to exercise full control over the process. This ability, through the and computer software,



use of appropriate sensors forms the basis of NITREG®.

WHAT IS NITREG®?

Brief Description of NITREG® Potential-Controlled Nitriding

Nitreg® is a family of nitriding and derivative processes built on the principles of:

- control of the nitriding potential,
- modern equipment design with superior performance and reliability,
- automation and computerized controls,
- high precision control devices and instrumentation,
- ease of operation and fool-proof nature of using the equipment in an industrial environment,
- know-how reflected in thousands of process setups,
- guaranteed metallurgical results.



NITREG® POTENTIAL-CONTROLLED NITRIDING

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HOW IS IT CONTROLLED?

Equipment & Process

In the Nitreg® technology, the following aspects of the process and the results can be controlled:

- to **maintain the appropriate nitriding potential** in each stage, the process is controlled automatically through:
 - a) a sequence of stages with appropriate parameters,
 - b) gas mixtures and flows,
 - c) temperatures;
- in addition the following system functions are also computer-controlled:
 - a) pressure in the furnace,
 - b) functioning of valves, flow measuring devices, heating, cooling, etc.,
 - c) alarms and automatically executable emergency procedures,
 - d) data collection;
- no operator involvement is required at any time during the process,
- the phenomenon of diffusion is the same as in any other well run, high quality nitriding process – it is a function of temperature and time in a suitable atmosphere,
- ability to produce predominantly single phase (γ' or ϵ) or mixed nitrides, or develop a diffusion case with zero white layer.

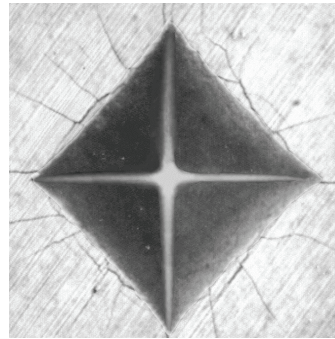
The most significant characteristic of the Nitreg® family of nitriding technologies is our ability to control the development of the diffusion case separately from the compound (white) layer. As hard to believe as it is, we are able to produce any case depth combined with

any white layer thickness, within the practical ranges such as:

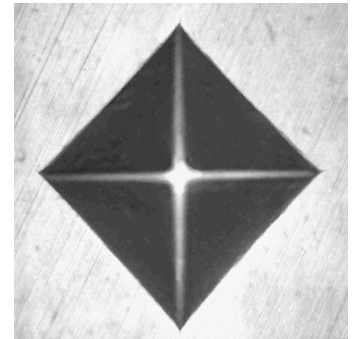
- case depth will rarely be specified to exceed 0.035" (900 μm), with most applications falling in the 0.004" to 0.012" (100 μm to 400 μm) range, and
- white layer should generally be within the zero to 0.001" (25 μm) range, with most applications in 0.0001" to 0.0005" (2.5 μm to 12.0 μm) range.

Typical hardness results, as well as white layer and case depth recommendations for other alloys may be found throughout Nitrex's technical papers and brochures.

Vickers indentations (load of 30 kg) on 4340 steel, nitrided to same specification.



Conventional nitriding process



NITREG® nitriding process

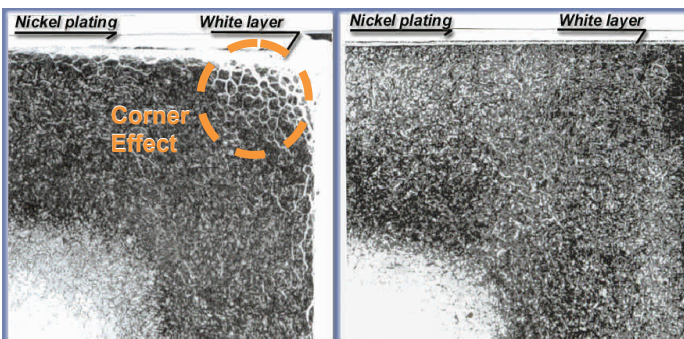
WHY NITREG®?

Reasons to Use the NITREG® Process

The reasons to use this process in preference of any other nitriding method are as follows:

- complete and independent control of the white layer and diffusion case,
- major improvement in control of the surface chemistry over conventional gas or salt treatment, and similar in capability to well controlled plasma (ion) processes,
- uniformity of results regardless of parts positioning in the furnace, including almost total lack of sensitivity to any contact between the parts, or between the parts and the racking system or baskets,
- elimination of closed nitride networks within the diffusion zone,
- control of surface hardness,
- no distortion, and minimal and predictable growth.

Nitreg® is a process in which any steel and certain other alloys may be nitrided, with complete control over the formation of nitrided layers.



Conventional nitriding process

NITREG® nitriding process

CORNER EFFECT is the over-saturation of nitrogen in the white layer and in the diffusion layer which leads to spalling. Nitreg® prevents this effect by appropriately reducing the nitriding potential (K_N) during treatment. The concentration of nitrogen in the corner is lowered sufficiently to prevent over-saturation.

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WHAT CAN BE TREATED?

Materials & Applications Suitable for NITREG® Treatment

The following types of alloys are successfully treated:

- carbon steels
- alloy steels
- cast irons
- cast steels
- stainless steels
- nickel alloys
- steel-based high density powder metals
- titanium alloys

NITREG® DERIVATIVES

Additional Processing Methods

The Nitreg® technology has spawned several additional processing methods and treatments, described in other Nitrex brochures and technical papers, but listed here for reference:

- Nitreg®-C - ferritic and austenitic nitrocarburizing
- Nitreg®-S - nitriding of stainless steels and nickel alloys
- Nitreg®-Ti - nitriding of titanium alloys
- ONC® - in-process post nitriding (nitrocarburizing) oxidation
- Corr-Check® - high performance rust preventative

INDUSTRY-WIDE SPECIFICATIONS & RESULTS

Discussion of Applicable Specifications & Achievable Results

The most applicable industry-wide specification is AMS 2759/10, the most recently issued standard for the aerospace industry. In addition Nitreg® is capable of meeting all nitriding specifications, in terms of metallurgical results, ever published and achievable by any nitriding process currently available on a commercial basis.

ALTERNATIVES

What Alternatives could be Considered & Why

In selected applications, plasma (ion) nitriding may be considered, the possible advantages being easy masking, or nitriding of low density powder metal components. Carburizing, carbonitriding or induction hardening will be considered, however, this usually necessitates a change in the alloy used, and the risk of distortion must also be taken into account.

WHY NITREX?

Reasons for Selecting Nitrex to be Your Subcontractor

Nitriding tradition and experience in the Nitrex's team of engineers and scientists stretches back continuously through three generations all the way to 1950. Our team never backs away from even the most challenging nitriding or nitrocarburizing application. Ask us for an advice about which nitriding method is better suited to your situation. If your drawing calls for "salt", or "plasma", or any other nitriding we are at your service.

LOCATIONS COAST-TO-COAST

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