

# *Molten Salt Cleaning of Engine Components*

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by

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# Molten Salt Cleaning of Engine Components

## *An Alternative Cleaning Technology*

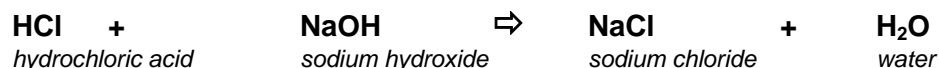
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### Introduction

Molten salt cleaning processes find broad applications in the cleaning of used engine components in preparation for inspection and remanufacturing. Molten salts offer a combination of performance, speed, thoroughness, and flexibility not available in other chemical or thermal cleaning technologies. This paper will describe the characteristics of the process in detail.

### Molten Salts - What are they?

They are simply a class of inorganic chemical compounds, heated to some temperature above their melting points to form a working fluid. There are literally thousands of chemical compounds that fall into the general classification of a salt. Table salt, or sodium chloride, is probably the first thing that comes to mind when one hears the term molten salt. While it is indeed a salt, common table salt finds little use in the formulation of cleaning molten salts due to its high melting point and low reactivity. A salt is formed when an acid and a base react:



By combining the building blocks of inorganic salt compounds, a variety of melting points, chemical reactivities, and degrees of stability can be achieved for a working bath. These baths find broad industrial applications for the treatments of metals:

- neutral heat transfer medium
- heat treating (carburizing, nitriding, etc) medium
- chemically active cleaning medium

## Salt Bath Applications

### **Casting Cleaning**

for removing

- sand
- scale
- graphite
- shell
- core
- facecoat

### **Descaling**

to condition and descale

- stainless steels
- superalloys
- titanium
- refractory metals

### **Organic Stripping**

to strip parts & racks of

- paint
- powder coatings
- polymers

### **Engine Remanufacturing**

cleaning used cores of

- oils / soils
- carbon
- paint

### **Jet Engine Overhaul**

cleaning blades, buckets of

- carbide coatings
- service scale
- sulfidation

### **Salt Bath Nitriding**

to upgrade engineering properties such as

- fatigue resistance
- wear resistance
- gall resistance
- lubricity

## What are they used for?

You may already be familiar with the results of some molten salt processes. Salt bath carburizing processes are widely used for engine gears, pinions, and other heavily loaded functional components. Salt bath nitriding (SBN™) finds broad use in components that require exceptional wear and fatigue resistance. Typical applications of SBN treated parts include automotive engine valve stems and gas spring rods (to replace chrome plating), and high performance crankshafts and camshafts (for upgrading wear and fatigue resistance).

The use of molten salt for cleaning components is widely accepted by industry. In foundries, components routinely cleaned range in size from dental castings to locomotive cylinder liners. Aerospace components range from forged titanium blades in jet engines to superplastically - formed airframe structural components. See the sidebar summary (left) for a brief overview of salt bath applications.

## Molten Salts as a Cleaning Medium

The formulations involved with chemically active, cleaning-type molten salts are generally based on alkaline hydroxides and select additives. They may be broadly classified as chemically reducing, neutral, or oxidizing depending on their formulation and intended use. The chemically reducing baths find little application in engine manufacturing or remanufacturing. The neutral-type baths are generally used for dissolving or leaching sand, quartz, and ceramics from castings at the foundry level. They may be used "as-is", i.e. a simple immersion-type process, or with the application of direct current for more sophisticated cleaning applications. An example of the electrolytic molten salt process is Kolene® Kastech® Electrolytic®. It is used for sand, scale, and graphite removal from cast iron at the foundry or OEM stage of manufacturing. This facilitates improved heat transfer, allows brazing and babbiting of cast iron, and prevents in-service failures due to scoring and seal failures from retained sand.

## Molten Salts in Engine Remanufacturing

Molten salt bath cleaning of used heads, blocks, cranks, etc in preparation for remanufacturing is a fast, thorough, and versatile process. It is unique, in that it is a 100% active chemical melt; there are no solvents, diluents, water, etc involved with the molten bath. It is liquid solely because of

its operating temperature. There is no evaporation or loss of “liquid” from the bath as it has negligible vapor pressure at normal operating temperatures. It’s important to note that there are no evaporative energy losses from the working bath, either. In many instances, the energy requirements for a molten salt cleaning system are actually less than the hot boiling aqueous cleaners they supplant.

One of the unique properties of molten salts is their high heat capacities. Typically around 0.5 (water = 1), they are an excellent heat source to bring workloads up from ambient temperature to working bath temperature in only a few minutes, without any chance of temperature overshoot. As the cleaning reaction begins and energy is liberated, the bath acts to absorb the heat and prevent any overheating or “hot spots” and their associated metallurgical changes during the process cycle. The high heat transfer rate, in concert with the high chemical reactivity of the bath, yields very short cycle times. Depending on the size of the workload and component geometry, cleaning cycles can range from as short as 10 minutes, with cycle times of 20 to 30 minutes being typical.

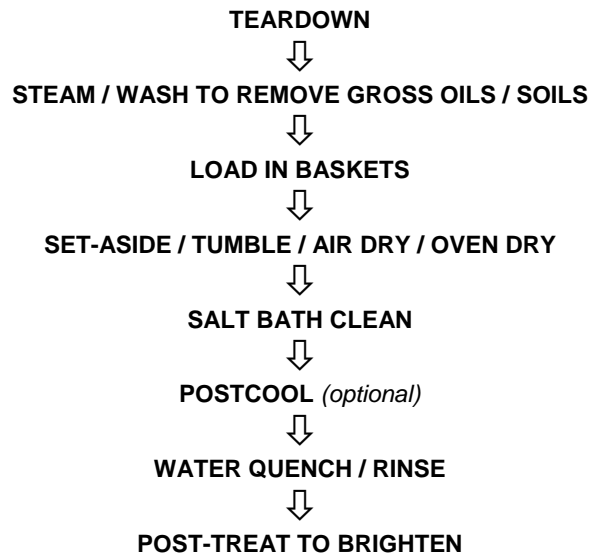
Any organic compounds that may be present on the used components - oils, soils, greases, paints, carbon - are quickly and completely converted to inorganic compounds by thermochemical oxidation. More volatile components may vaporize rapidly and escape to the surface of the bath, while higher boiling point organic liquids are consumed in the bath. Inorganic deposits such as water scale are moderately affected by the bath. Thick metal scales such as rust and heat scales are not removed by the bath, but any organic oils or soils that were absorbed into them during service are removed; this greatly increases the efficiency and effectiveness of subsequent chemical brightening or pickling operations after salt bath cleaning.

Due to the speed of the process, specialized air handling equipment is needed for salt bath remanufacturing cleaning systems. Since all of the volatile compounds are generated in a very short period of time, wet scrubbers are usually used to capture and clean the exhaust air. Typical exhaust air flow rates of up to 20,000 scfm help to assure that a negative pressure is maintained within the system hooding. These requirements for a 15 to 20 minute start-to-finish cleaning cycle contrast to a thermal bakeoff cycle of 6 hours or more with its afterburner or catalytic converter.

While molten salt processes are capable of removing all of the organics and soils which may be present on a used engine, the best use of the molten salt is as a scavenger or finishing tool. It will quickly remove the remainder of any oils, sludges, and paint left on the component after minimal precleaning and, at the same time, completely digest high-temperature stable deposits such as coke and carbon. While not capable of completely digesting gasket materials, it does degrade the gasket-to-metal bond.

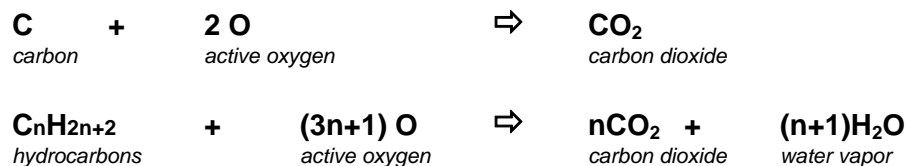
## Process Flow

The following flowchart summarizes the cleaning process:



Due to the rapid heat-up rates inherent with molten salts, it is imperative that all components introduced into the bath be free of water. The rapid evolution of steam from water - especially if it occurs beneath the surface of the molten salt - may result in the expulsion of the hot salt and damage and/or injury to process equipment and personnel.

When a load of components is first immersed in the molten salt, a “cocoon” of solidified salt forms on the cold workload. As the load heats up, the solid salt remelts and the reaction between the soils and salts begins. Low boiling point / high vapor pressure organics will vaporize and react with the salt; depending on the amount present, some of the vapor will escape from the bath and ignite above its surface. Unignited vapors condense upon cooling and are removed in the air exhaust wet scrubber. More thermally stable species such as paint, coke, and carbon are thermochemically oxidized by the bath to inorganic byproducts:



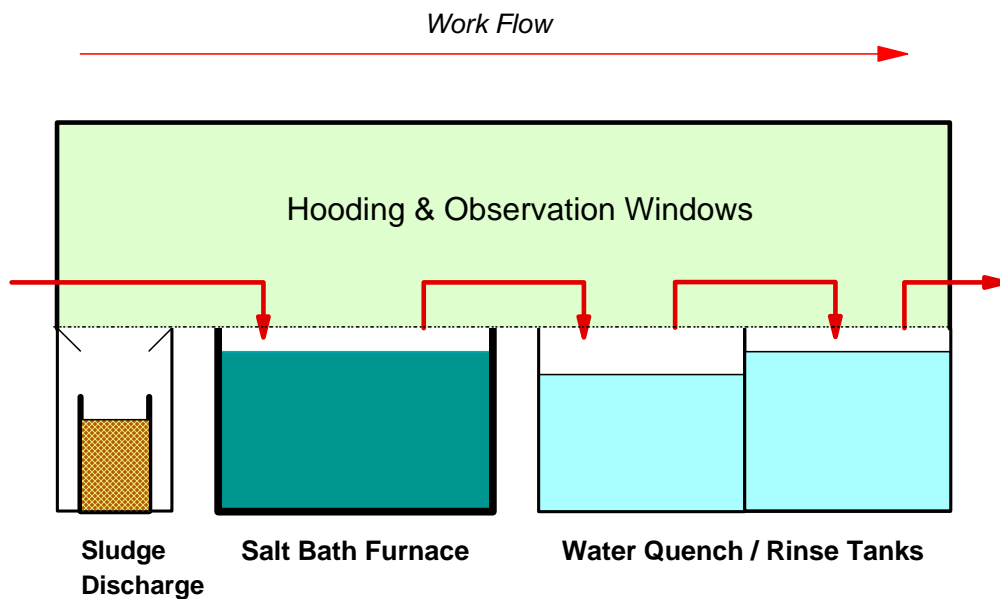
The carbon dioxide formed during the “chemical combustion” of the paints, oils, and carbon deposits further reacts with the alkaline hydroxides present in the bath to form alkali carbonates:



It is the unique combination of the molten salt bath's temperature and chemistry which allows these cleaning reactions to take place very rapidly, thoroughly, and at temperatures well below those needed with simple thermal cleaning methods. As more and more organics are introduced into the bath, alkali carbonates continue to form as the principal reaction byproduct. Inorganic contaminants which may be present on the used components may take many forms. These include heavy metal paint pigments, bearing wear fines, water scale, etc. All of these remain in the bath, and eventually accumulate in the sludge or byproduct collection system for subsequent removal. One of the important characteristics of molten salt processes is their ability to react even when saturated with reaction byproducts. The working baths never need to be "dumped". Through the routine removal of accumulated reaction byproducts and additions of fresh process chemicals, the working bath continues to perform in a predictable, dependable manner.

### Process Equipment

Due to the chemical, thermal, and operational characteristics of molten salt processes, specialized equipment is required. The basic requirements include the salt bath and its heating system, byproduct collection and discharge modules, and at least one rinse tank. For operator safety and to collect and vent reaction offgasses, hooding with observation windows is a necessity. The basic minimal elements are sketched below:



*Basic elements of and workflow for a typical molten salt bath cleaning system.*

In practice, each unit is custom designed, engineered, and fabricated to a specific customer's requirements. Some of the more important design input criteria are:

- largest component geometry
- operating hours per day
- post-treatment tanks under hood
- required throughput
- manual or automated handling
- amount of soils / oils

These criteria - along with basic design considerations such as floorspace, line configuration (straight-line, "U", or loop monorail), and degree of automation desired - help to shape the final design. Actual equipment sizes vary from very small systems for low volume work, to very large, fully automated systems. The range of size can be seen in the photos below.



*Equipment size is based on required throughput and component dimensions. Handling systems range from manual hoists to fully automated "pick and place" transfer units.*

## **Remanufacturing Applications**

After teardown, draining, and minor precleaning, the dry workload is immersed into the molten salt for stripping of all organics - oils, greases, paints, and coke/carbon deposits. Orientation of the parts is important. Air pockets will prevent salt contact and result in incomplete cleaning. Large dished or cupped areas unnecessarily drag out large amounts of salt and impact both operating expenses and quench/rinse water cleanliness. The relatively small amount of time spent in properly fixturing or orienting the parts is well worth the effort.

After a predetermined time, the workload is removed and any excess salt is allowed to drain back into the bath. Depending on the quench sensitivity of the parts being cleaned, the work is either directly quenched into water, or allowed to air cool before quenching. After water rinsing, there will be a thin, tight iron oxide coating on ferrous materials. This is due to the oxidizing nature of the cleaning bath. Chemical post-treatments such as chelated alkaline derusters or inhibited acid pickling solutions are commonly used to complete the cleaning process and produce a clean, metallic appearance.



Ferrous components are the most common parts to be cleaned in molten salt. Select non-ferrous parts such as aluminum can be successfully cleaned, but it should be noted that the temper or hardness of the aluminum will be reduced because of the bath's operating temperature of ca. 700° - 800° F. If the design of the component is such that the reduction in temper will not adversely affect it in service, it is a good candidate for salt bath cleaning. Certain metals such as magnesium or zinc die cast may not be processed in an oxidizing molten salt. Magnesium will ignite and burn, while zinc die cast may exhibit excessive surface blistering or "pimpling" as a result of dissolved gasses building up pressure.

Below is a series of "before and after" photos of typical components.

*Cast iron engine blocks & heads and alloy engine valves are typical of the components which are salt bath cleaned.*



*In these three photos, the left components are after teardown.*



*In the middle are the results of salt bath cleaning and water rinsing. The red iron oxide is the result of the oxidizing nature of the molten salt.*

*The right components are after salt bath cleaning and subsequent chelated alkaline brightening, and represent the "finished" product of the cleaning operation.*



The aluminum turbocharger bearing housings at the right represent an instance where salt bath cleaning replaced mechanical shot blast methods. Shot blast - while successful in cleaning the components - was masking hairline cracks and other defects that were leading to warranty claims. Salt bath processing was able to thoroughly clean the used components and allow for easy and accurate inspection for potential flaws.

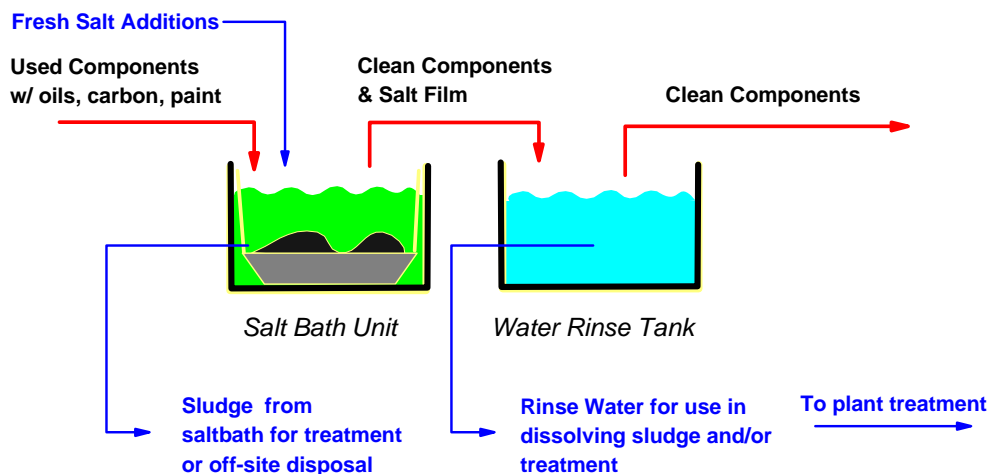


### Process and Environmental Overview

In order for the process to continue to clean components in a consistent and predictable manner, reaction products (sludge) must be routinely removed from the bath. Formed in proportion to the organic loading, sludge consists of inorganic compounds resulting from the thermochemical oxidation of the paints, oils, greases, and carbons present on the work. Also included in the sludge are any inorganic compounds that were originally present: dirt, sand, metal oxides, scales, metal fines, gasket residues, etc.

All of these byproducts settle out of the working bath by gravity, and are accumulated in a sludge pan located in the bottom of the salt bath. When these insolubles are removed, the working level of the bath drops slightly. To make up for this level loss, additions of fresh

### Process Flow



process chemical are made to the bath. This not only restores the working bath's physical level, but also helps to maintain the proper bath chemistry. It is through this routine removal and addition procedure that the bath continues to perform *ad infinitum*; the bath does not have to be routinely "dumped" and recharged, as is common with most chemical cleaning processes.

The sludge is a 100% inorganic material and, as such, is largely water soluble; any and all insoluble organics that were introduced into the working bath have been destroyed. While there are no heavy metals in the process chemicals *as supplied*, the sludge will probably contain heavy or restricted metals as the result of the processed work. The most common heavy metal is lead (from bearing wear and fuel additives), but other heavy metals such as barium, cadmium, zinc, etc may also be present. Sources of these metals include paint pigments, platings, lubricant additives, etc. For these reasons, the sludge is considered a hazardous material under current federal regulations.

The sludge may be either processed in-house, or sent off-site for proper treatment and disposal. Since the vast majority of the sludge is water soluble, treatment is relatively easy and uncomplicated. Before any treatment may begin, it is necessary to make a water solution of the sludge. Quench water, fresh water or combinations of the two may be used for this purpose. A typical solution will contain about one pound of dissolved sludge per gallon of water. The main characteristics that need to be addressed include:

- high pH due to carbonates and occluded salt
- potential heavy metals content
- suspended solids

A typical treatment regime will include adjustment of the pH through the addition of a mineral acid such as sulfuric, or bubbling gaseous carbon dioxide through the solution. If sulfuric acid is used, sodium / potassium sulfate will be formed. Analogously, sodium / potassium bicarbonate are formed when carbon dioxide is added. The solution will then need to be treated to remove any heavy metals, typically through the addition of a chemical reducing agent. This results in the chemical reduction of the dissolved metal species, and in conjunction with appropriate pH conditions, renders the metals insoluble. The final treatment step is to filter out these insolubles and then properly dispose of them.

Depending on the quantity and type of restricted metal(s) present, the ultimate disposal classification is typically determined by performing a Toxic Characteristic Leaching Procedure (TCLP) on the filter cake. In many instances, the cake will pass the leaching test even when restricted metals are present.

## **Conclusions**

Molten salt processing of used engine components is a very thorough, rapid, and robust industrial cleaning process. It is ideal where very complete cleaning and rapid turnaround are required. Specialized safety-engineered equipment allows these processes to be placed on the general plant floor, and provides convenient and efficient operation. Through routine byproduct removal and fresh salt additions, molten salt baths are capable of indefinite operation without periodic dumping and recharging.



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