

# Material Matters

## AOD Metal Refining Process

- Maximizes operational efficiency, minimizes cost

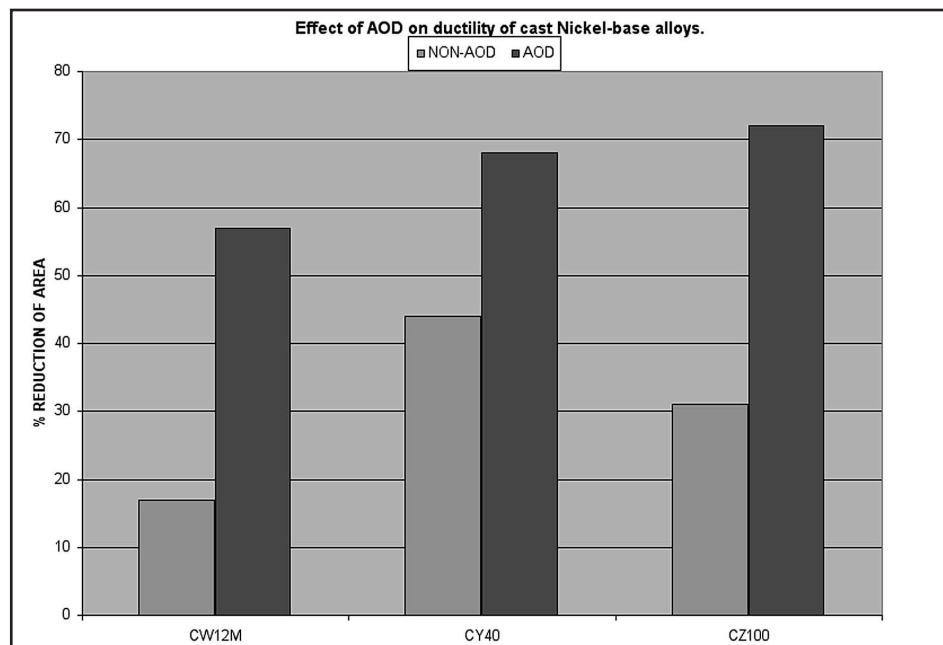
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 Foundry Operations, Ashland, PA

On February 10th, 2000, the Ashland Foundry poured it's first heat of AOD (Argon Oxygen Decarburization) refined metal. The equipment and the process technology was purchased from AOD Systems, a unit of Praxair. Most of the installation was performed by our Maintenance Department, with the concrete foundation work being sub-contracted. The purchase and installation of this system is a milestone for the Ashland Foundry. Inflation continues to drive raw material costs upwards and squeeze foundries' profit levels to the point of economic failure. The AOD system positions Goulds Pumps to purchase the lowest cost raw materials and still provide the highest quality end product. It will help Ashland Foundry to remain cost competitive in the years to come.

Argon Oxygen Decarburization (AOD) is a proprietary steel refining process. The system operates by transferring molten metal into a brick-lined vessel and injecting oxygen and inert gases (argon or nitrogen) through tuyeres. The controlled injection of process gases decarburizes the molten metal with a minimum of unwanted metallic oxidation. Since the oxygen and inert gases are introduced below bath level and at high velocity, excellent bath mixing and slag-metal contact occur. As a result, all the chemical reactions that take place within the vessel are greatly improved. These include desulfurization to very low levels (under .005%), increased carbon removal efficiency, and efficient slag reduction to allow recovery of 99-100% of most metallics. Heat generation results from controlled oxidation of the molten metal bath components and no external heat source is employed or required.

The superior mixing and degassing capabilities of AOD results in improved metal cleanliness, which enhances mechanical properties and reduces casting cleaning room costs.

This addition to the Ashland Foundry's melting department allows the use of lower cost raw materials without sacrificing metal quality. It also allows the Melting Department to



use more of it's return scrap in each charge make-up and eliminate the need to send our return scrap to outside vendors for expensive metal refining in order to make it useable.

Unlike the older generation AOD systems, where vessel operations and calculations were manual, the new systems are computer driven with refining and least cost addition programs for each grade we produce. Our system utilizes the Praxair Intelligent Refining System (IRS). This computer-based gas, equipment, and process control system operates by a user-friendly Windows environment. The IRS capitalizes on more than 25 years of Praxair experience with AOD process development and equipment technology. The system provides true integration and control of all steps in the AOD process and simplifies its operation.

"Artificial intelligence" enables the Intelligent Refining System to model carbon content and temperature during decarburization and to control the reduction temperature and chemistry much more accurately than was previously possible. An "AOD Wizard" program, sequences and performs all tasks and calculations, including automatic vessel positioning, process gas selection and proper gas ratio selection, and alloying requirements. Computer-controlled, standardized operating procedures ensure unparalleled consistency. The AOD refining process for molten metal can be broken down into three major steps: Decarburization, Reduction, and Final chemistry and temperature trim.

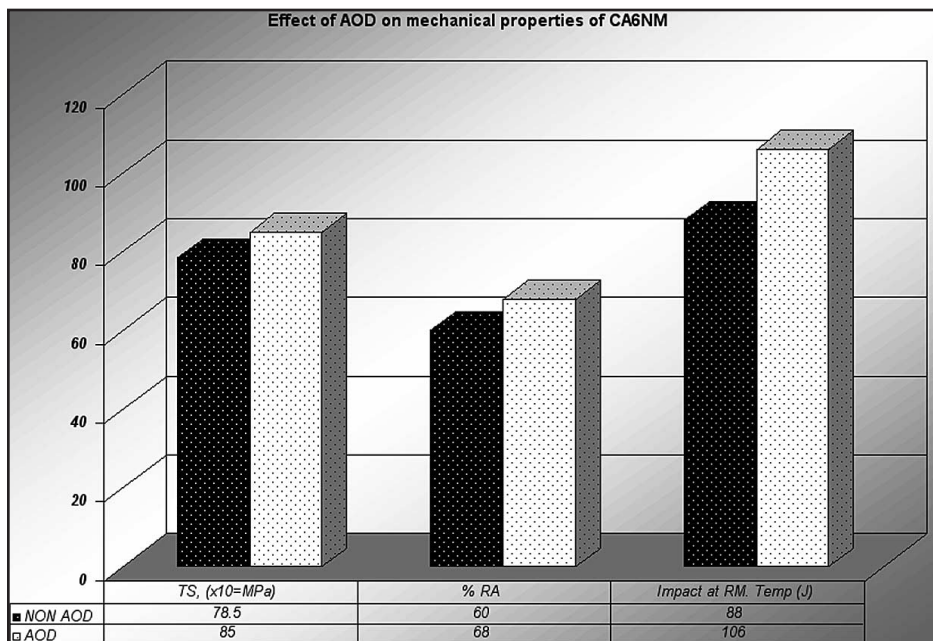
During the decarburization step the "AOD Wizard" calculates the amount of oxygen needed to produce the desired carbon content and temperature for the finished steel. The system also calculates the progression of ratios of oxygen to inert gas (nitrogen and/or argon) throughout the entire decarburization blow. During this first step the IRS is calculating the least-cost additions to achieve the final aim chemistry for the melt. The "AOD Wizard" rotates the AOD vessel to the proper position for blowing, sampling, charging, or making additions, and injects the appropriate gases during each of these operations.

As soon as the decarburization step is complete, the IRS will calculate the amounts and types of reducing agents and fluxes that must be added to ensure proper bath reduction. It will also calculate any fuel and gases necessary to provide the desired temperature at the end of reduction.

Based upon a metal chemistry taken at the end of the reduction step, the "AOD Wizard" calculates the least-cost additions to meet specified chemical compositions, and by controlling the processing steps, controls the associated bath temperatures. The system will ensure that the molten metal temperature is within the specified pouring range.

AOD refined steel provides improved metallurgical characteristics in comparison to conventionally melted steel (induction or arc-furnace). Final levels of gases, (oxygen,

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hydrogen, & nitrogen), sulfur and inclusions, are considerably lower because of the inherent processing capabilities of the AOD process. This "cleaner" metal will have enhanced fluidity and pouring temperatures can be lowered 50°F-100°F depending on the particular grade of steel and the configuration of the casting being poured. Superior final product cleanliness leads to metallurgically tougher and more ductile metals than was previously obtainable by conventional melting methods. AOD processed steels see reduced times in the cleaning room because the rate and size of inclusions are considerably smaller.

## Enhanced Mechanical Properties

As has been previously mentioned, the AOD has the advantages of processing steels into superior quality metals by controlling chemistries to tight ranges, ability to reduce carbon levels in corrosion resistant grades to .01% or lower; sulfur levels of .010% or lower are easily obtained; lower residual "tramp" elements are eliminated; and lower residual nitrogen, oxygen, and hydrogen. All these factors lead to a steel that is more dense, more ductile, and has improved toughness over conventionally melted steels.

In the production of corrosion resistant stainless steel, in particular, CA6NM, CD4Mcu, CN7M, and CA15, the precise control of carbon to extremely low levels eliminates many production problems. Not only is the castability substantially improved, but the weldability is also markedly enhanced, especially in thick sections. Such problems as under-riser and under-bead cracking are readily controlled through superior metal refinement. Similar results for carbon steels, high strength alloys, and nickel-base alloys have been realized. The two graphs shown in this article present published property data of various grades of AOD refined steels in direct comparison with conventionally melted steel.

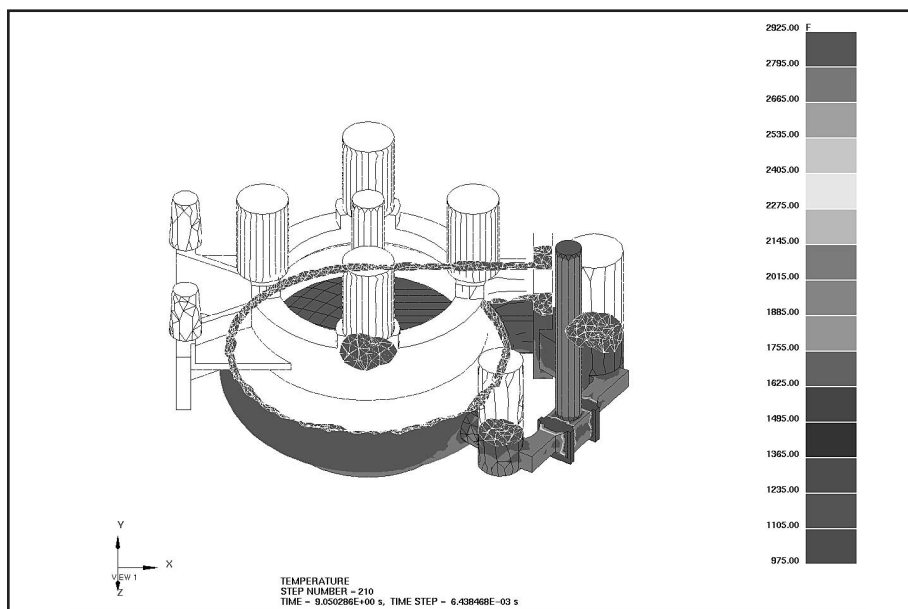
## Economics Of Duplex Stainless Steel (2205) Via AOD

The recent addition of the AOD process to the Goulds Pumps, Ashland Foundry could not have come at a better time. Initially, the cost justification for this capital project was mainly lower cost raw material savings, inventory reduction, and metal quality improvement. All three of these components we have realized rather rapidly.

Another important characteristic of the AOD refining process is its ability to generate grades of stainless steels with very low carbons from low cost, high carbon raw material. This allows us to produce low carbon duplex stainless steels very economically.

Demand from some industries for conversion from austenitic stainless steels to duplex stainless steel grades, specifically alloy 2205, is increasing. The main reason for this switch is cost efficiency. This is because of the lower nickel content and high mechanical properties. The second reason for using duplex stainless steels is their corrosion-resistant properties. They perform much better than the typical CF3M/8M grades. Pitting and crevice corrosion resistance are improved, as are stress corrosion cracking and fatigue corrosion. Nitrogen, which significantly improves pitting and crevice corrosion, is easily and accurately added to the molten metal with the AOD process.

Castings poured in alloy 2205 will process through the upgrade shop with the same ease as castings poured in typical austenitic stainless steel (CF8M). Welding of this material poses no problem and heat-treating of 2205 is very



AOD facilitates thin wall casting.

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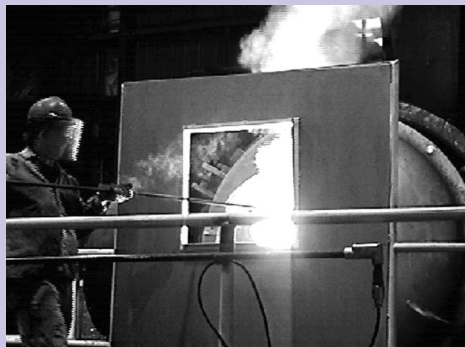
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flexible from the standpoint of the quenching media. Water, as well as forced air can be used. 2205 is the least prone of the duplex alloys to form sigma ferrite. Proper heat-treatments, and metal chemistry controls will provide the optimum cast material for the shop to process.

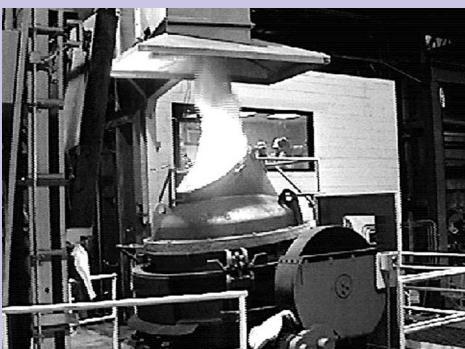
### Conclusion

Since the AOD's startup on February 10th, 2000, we have processed over 1000 tons. The system has already shown us many benefits in this short period of time. The "in-house" return scrap inventory has been dramatically reduced. Rework and scrap has been lowered by 22-34% over previous years. In addition, our weld rod expenditures are 43% below budget year to date. The AOD also allows us to purchase lower cost grades of raw materials to produce our steels. Thus we have lower raw material costs from a purchasing stand-point.

The AOD System has met our highest expectations. This investment has allowed us to position ourselves with the elite foundries in the marketplace, and will keep our costs and our customers costs as low as possible. ■



AOD vessel, Argon-Oxygen blowing.



Checking bath temperature.

## How to Pick the Right Nickel Alloy for Corrosive Services

**Stephen J. Morrow**

Global Manager Materials Technology  
ITT Industrial Pump Group

### Why the interest in Nickel alloys?

Chemical and other process industries utilize some of the widest range of materials, confronting many forms of corrosion. Successful operation and performance often depends upon nickel-base alloys, which are extensively used in pumps to resist the severe effects of corrosion, and provide trouble free service. Nickel alloys offer a combination of excellent corrosion resistance, heat resistance and mechanical properties; making them well suited for many aggressive applications.

Proper selection of materials is a critical engineering function. Advances in metallurgical knowledge and processing technologies have resulted in the development of many nickel alloys offering broad application. The difficulty lies in determining which alloy is best suited for what service.

The key to successful application of nickel alloys is understanding the materials chemistry; corrosion mechanisms; and taking adequate measures to minimize risk of degradation through appropriate materials selection. However, making the proper nickel alloy selection is sometimes difficult, and often seems complicated or confusing.

This article should help familiarize engineers with the common nickel alloys utilized within the pump industry, review their typical use, and provide guidelines for selection by characterizing them in terms of chemistry and performance. General guidelines for selecting which nickel alloy is best suited for what service shall be given.

### Nickel Alloy Metallurgy

One of the most significant attributes of nickel with respect to the formation of corrosion resistant alloys is its metallurgical compatibility with many other metals, such as copper, chromium, molybdenum, iron, and others. Nickel is resistant to a variety of corrosive media, and can readily alloy with most metals to form specific alloys for wide application.

Complete solid-solubility exists between nickel and copper, as well as nickel and molybdenum, resulting in binary alloys. Wide solubility with iron and chromium allows for many additional alloy combinations.

Nickel alloys are generally face-centered cubic fully austenitic alloys, however many can be precipitation hardened. For corrosion applications the precipitation of secondary phases usually reduces the corrosion resistance of the alloy, and as a result, is generally avoided.

To optimize performance, developers of nickel alloys have taken advantage of the fact those large quantities of other elements forms solid solution alloys in this face-centered cubic structure, without forming brittle phases. Common alloying additions for enhanced corrosion resistance are copper, molybdenum and chromium. The common groups of nickel alloys utilized in pumps can thus be classified according to their principal alloying constituents as follows:

- commercially pure Nickel
- binary alloys such as Nickel-Copper
- binary alloys such as Nickel-Molybdenum
- ternary alloys such as Nickel-Chromium-Iron
- ternary alloys such as Nickel-Chromium-Molybdenum
- complex alloys such as Nickel-Chromium-Iron-Molybdenum-Copper

Improved melting and processing technologies, as well as an improved understanding of the role of various alloying elements on the physical metallurgy have played a key role in the development of nickel-base alloys. The effect of various elements may be favorable or detrimental, depending upon the specific service application conditions.

### Effects of major alloying elements

To overcome the obstacles of more corrosive environments, nickel alloys offering higher levels of corrosion resistance were developed. Some have specifically added or deleted certain alloying elements to achieve specific characteristics. The alloy content determines the corrosion resistance.

As previously stated, **Nickel** provides a matrix that is metallurgically compatible, and forms a solid-solution with many other elements. This element