A.J. Fuller, Jr., Introduction to Carburizing and Carbonitriding, *Steel Heat Treating Fundamentals and Processes*. Vol 4A, *ASM Handbook*, ASM International, 2013, p 505–521.

How to Carburize

It is possible to create the conditions necessary for carburization through a wide variety of methods and equipment types, but all carburizing processes have the following characteristics in common.

Low-Carbon Base Steel. Steels for carburization typically have a carbon content ranging from 0.15 to 0.30%. The most common carbon content is approximately 0.2%, although occasionally steels with a carbon content as high as 0.50% are used for special applications. Carburizing steels can be plain carbon or low-alloy steels. They provide the substrate for the carburizing process as well as the material that will provide the core properties.

Carbon-Rich Source. This will contribute the carbon for diffusion into the surface of the low-carbon base steel. A variety of carbon-containing materials may be used. The carbon can be delivered as a solid, liquid, or gas. Historically, everything from charred animal bones to natural gas and methanol has been used. Gaseous media are the most commercially viable and constitute the bulk of the carburizing capacity in the world, although solid and liquid media are still used in special circumstances.

Heat. Carburization requires that the steel be able to accept carbon into its crystallographic structure. This is facilitated by the fact that the interstitial spaces available in the austenite unit cell are larger than those in the ferrite unit cell. These larger interstitial spaces make carbon significantly more soluble in austenite than in ferrite. To make carburization possible, the process must take place at a temperature above the Ac_1 temperature. Conveniently, carburization is a diffusion-based process, so the temperature required to transform the component to an austenitic structure also provides the necessary driving force to facilitate the diffusion of carbon from the medium into the steel in a commercially viable timeframe. The speed at which carbon diffuses into the surface is proportional to the temperature, so it is possible and often economically beneficial to operate the carburization process at the highest possible temperature in order to minimize processing time by increasing the diffusion rate. It is important to consider that the savings found in higher processing temperatures must be weighed against the increased cost of equipment maintenance.

Container. In most cases, the container will be a furnace with burners or elements to introduce heat energy, and inlets for the carbonaceous medium to enter and blanket the workpiece. The container (or vessel) must include some method of placing the workpiece and medium in intimate contact during the heating process. This container serves several functions: to prevent loss of the medium and to insulate the process to prevent excessive loss of energy. The container will also serve to isolate the surface of the workpiece from undesirable substances that can impede or reverse the carburization reaction, such as oxygen. Anything can serve the role of container if it performs these functions. Examples of common carburizing containers are provided in Table 2.

Table 2 Types of carburizing containers

Carburizing method	Container
Pack	Metal box
Liquid (molten salt)	The liquid salt itself serves to deliver the carbon and isolate the component from oxygen.
Gas/atmosphere	Furnace shell, positive pressure
Vacuum	Furnace shell, low pressure

Time. Carburization is a diffusion-based process, so time is required to effect the changes in carbon concentration necessary to achieve the desired properties. The length of time required will depend on many factors, including the desired depth of the high-carbon layer (known as the case depth) and the maximum temperature available (based on limitations of the container and energy source). For economic reasons, it is usually desirable to have the processing time as short as possible. This can be accomplished by increasing the process temperature, but this approach requires consideration of reduced equipment service life and increased maintenance costs, as well as possible undesirable effects on the component such as increased surface oxidation and grain growth. Usually, a compromise temperature is used that vides a reasonable balance between processing time and other factors.