Carryover Defined
Carryover is any contaminant that leaves the boiler with the steam. It can be in a solid, liquid, or vapor form. The most common form of carryover is boiler water droplets that contain dissolved and suspended solids.

Related Terms
Steam purity refers to the amount of solid, liquid, or vaporous contamination in the steam. High purity steam contains only trace amounts of carryover. Steam quality is a measure of the amount of moisture in the steam. It is the weight of dry steam in a mixture of water and steam. For example, steam of 98% quality would contain 2% moisture. Since steam containing entrained boiler water is by definition wet, both steam purity and steam quality are reduced by the presence of boiler water carryover.

Effects of Carryover
Boiler water carryover can cause deposits to form in non-return and stop valves, control valves, heat exchangers, turbines, and superheaters. If the deposits are significant, heat transfer and/or turbine efficiency damage may occur. Additionally, carryover can strip away the protective film formed by filming amine programs, cause erosion induced corrosion, and result in product quality problems in processes using live steam.

Turbines are particularly prone to damage by carryover. Solid particles in the steam will erode turbine parts while deposition on turbine blades will reduce efficiency, cause vibration, and result in turbine failure. The thermal and mechanical shock associated with large slugs of boiler water carryover can cause rapid turbine damage.

An often overlooked consequence of boiler water carryover is the efficiency loss due to wet steam. Since water at a given pressure has lower heat content than steam, wet steam has lower heat content than dry steam.

Causes of Carryover
The causes of carryover are generally classified as either mechanical or chemical. Mechanical causes include boiler design, high water level, firing method, and load characteristics. Chemical causes include high solids concentration (dissolved and suspended), excessive alkalinity, grease, oil, and other contamination.

Mechanical Causes
Boiler design directly influences steam purity. Design factors that affect carryover include design pressure, steam drum size, design steam generating rate, circulation rate, and the type of mechanical separating equipment used. Operating characteristics also directly influence steam purity. If a boiler is operated at loads in excess of its design rating or is subject to sudden increases in load, the potential for carryover dramatically increases.

Chemical Causes
Foaming and selective vaporous carryover are the two main mechanisms of chemical carryover. High suspended solids, high dissolved solids, high alkalinity, and process contamination from the condensate system can all cause foaming. In some plants, the dissolved solids level is the primary factor controlling whether carryover occurs while in others it is the alkalinity level. While suspended solids on a part-per-part basis tend to have a more pronounced impact on carryover than dissolved solids, the widespread use of external treatment has substantially reduced carryover due to suspended matter. Oil, grease, and other organic contaminants can also cause carryover due to foaming. Selective vaporous carryover occurs due to the solvent properties of steam. At high pressures, steam actually dissolves a portion of the mineral salts in the boiler water. While this is not a concern with most common minerals at pressures less than 1,000 psi, vaporous carryover of silica can occur at pressures as low as 600 psig. Consequently, the boiler water silica level must be carefully limited in higher pressure systems, especially if turbines are present.
Prevention of Carryover
The prevention of carryover can also be divided into mechanical and chemical means.

Mechanical Prevention
Low capacity and low pressure boilers (typically firetube boilers) primarily rely on simple gravity separation of the water and steam. At higher pressures and/or high steaming rates (typically water tube boilers) it is necessary to install internal mechanical steam separating devices to provide acceptable purity steam. These devices may consist of baffles, screens, chevron separators, or centrifugal separators. It is important that each element of steam separation equipment be kept clean and tight. Even a quarter inch gap between sections of cover baffles over the generating tubes can negate their operation. Likewise, the presence of deposits on screens or mesh demisters can prevent them from functioning properly. If the steam load is consistently at or above the rated capacity, a steam flow regulator (orifice) can be installed on the outlet of the steam drum, usually between the non-return valve and the steam drum.

Chemical Prevention
The principle chemical factors causing carryover are the dissolved solids, suspended solids, alkalinity, silica (vaporous carryover), and oil contents of the boiler water. In many cases, limiting the concentration of these components will satisfactorily control carryover. The actual levels that can be maintained without carryover problems can only be determined based on operating experience with each boiler system.

Chemical Antifoams
It is often possible to add a treatment chemical to the boiler water that will counteract foaming. These chemicals, called antifoams, can control carryover to a tolerable level without increased blowdown or additional external treatment. Their use can even reduce fuel consumption by permitting lower blowdown rates while maintaining high purity steam. While antifoams will not control all types of boiler water foaming, they should be considered whenever foaming is a problem.

Testing for Carryover
The occurrence of boiler water carryover can usually be verified by testing the condensate. As a general rule, low conductivity condensate indicates high purity steam is being produced, while high conductivity condensate indicates the presence of carryover.

Note that high conductivity alone does not necessarily indicate the presence of boiler water solids in the steam. In systems using highly alkaline makeup water, the carbon dioxide gas generated by the breakdown of the natural alkalinity in the makeup water can cause large amounts of carbonic acid to form in the condensate. Whether neutralized or not, carbonic acid will contribute significantly to the conductivity of the condensate. When highly alkaline makeup water is used, it is possible to have high condensate conductivity, although no boiler water solids are present. Also, if a leaking heat exchanger allows any type of water that has significant conductivity to enter the condensate system, the conductivity of the condensate may increase. This water may be hard or softened potable water or treated closed loop water.

If boiler water carryover is suspected, it can be verified by testing the condensate for such parameters as phosphate, alkalinity, silica, or sulfite. If significant levels of these contaminants are detected, boiler water is being “carried over” into the steam. If softened, hard or treated water is the suspected source of condensate contamination then running conductivity, hardness, alkalinity, silica, chloride and closed loop treatment tests may help pinpoint the source of contamination.

Conclusion
Even the most well-designed and operated boiler with a controlled water treatment program will produce at least minor amounts of carryover. The key is to know how much carryover can be tolerated and then operate the boiler system as required to provide the desired steam purity. Consult your Chem-Aqua representative to determine acceptable operating parameters.