Heat Treat Protective Atmospheres

Atmosphere	Source	Approximate Composition %	Processes	Metals	Advantages	Disadvantages
1) Rich Exothermic	Partial combustion of fuel gas	9-12 CO 11-15 H2 7-5 Co2 2-3 H2O 1-2 CH4 Balance N2	Normalizing, copper brazing and sintering	Ferrous metals	Cheap	Can cause decarburization and sooting
2) Lean Exothermic	Partial combustion of fuel gas	0-3 CO 0-4 H2 10-13 CO2 2-3 H20 Balance N2	Bright and clean annealing	Copper Nickel Brass Aluminum	Cheap, non-explosive	Fuel Gas can have NO sulphur; traces of O2 near full combustion
3) Rich Stripped Exothermic	Partial combustion of fuel gas, with CO2 and H2O removed	10-13 CO 12-15 H2 Balance N2	Substitute for 6)	Ferrous Metals	Relatively Cheap; Non-decarburizing	Can cause sooting; increased plant size and sometimes increased maintenance over 1)
4) Lean Stripped Exothermic	Partial combustion of fuel gas, with CO2 and H2O removed	0-3 CO 0-4 H2 Balance N2	Annealing; carrier gas for carbon restoration	Ferrous metals	Relatively Cheap; Non-decarburizing; non-explosive	3) and traces of O2 near full combustion
5) Modified stripped Exothermic	Partial combustion of fuel gas, with CO2 and H2O removed	3-12 H2 Balance N2	Long cycle annealing	Low carbon and mild steel	Non-sooting; cheaper than 8)	
6) Endothermic	Catalytic reaction of fuel gas and air	20-25 CO 30-45 H2 0.5–1.0 CH4 -15 to +15C DP	Hardening; brazing and sintering; carrier gas for carburizing and carbonitriding	Ferrous metals	Non-decarburizing	Explosive; can cause sooting; good maintenance and control required
7) Cracked Ammonia	Catalytic cracking of ammonia	75 H2 25 N2 -15 to –70C DP	Bright and clean annealing; sintering and brazing	Stainless and other steels; certain copper and nickel alloys	Pure; cheaper than 10)	Explosive; can cause nitriding effects
8) Partially burnt Ammonia; fully burnt Ammonia	Catalytic oxidation of ammonia	0.5-25H2 Balance N2	Bright and clean annealing; sintering and brazing	Stainless and other steels; certain copper and nickel alloys	Pure; cheaper and less explosive than 7)	
9) Hydrogen	Cylinders	>99.99 H2	Bright and clean annealing; sintering and brazing, BUT where nitriding must be avoided		Very Pure; no nitriding effects; low capital	Expensive; explosive
10) Nitrogen	Cylinders as Liquid	>99.99 N2	4) and 9) but more exacting applications		Pure; non-explosive; inert to most metals; low capital	Expensive
11) Argon	Cylinders as Liquid	>99.99 A	Bright annealing and other heat treatments on special components	Titanium; special steels; Nimonic alloys	Non-explosive; inert; low capital	Very Expensive
12) Steam	Electric Boiler	>99.9 H2O	Tempering and blueing; bright annealing	Steel; Copper	Very cheap; non-explosive	Condensate difficulties

Source: Handbook of Industrial Gas Utilization, Van Nostrand Reinhold Company, 1977