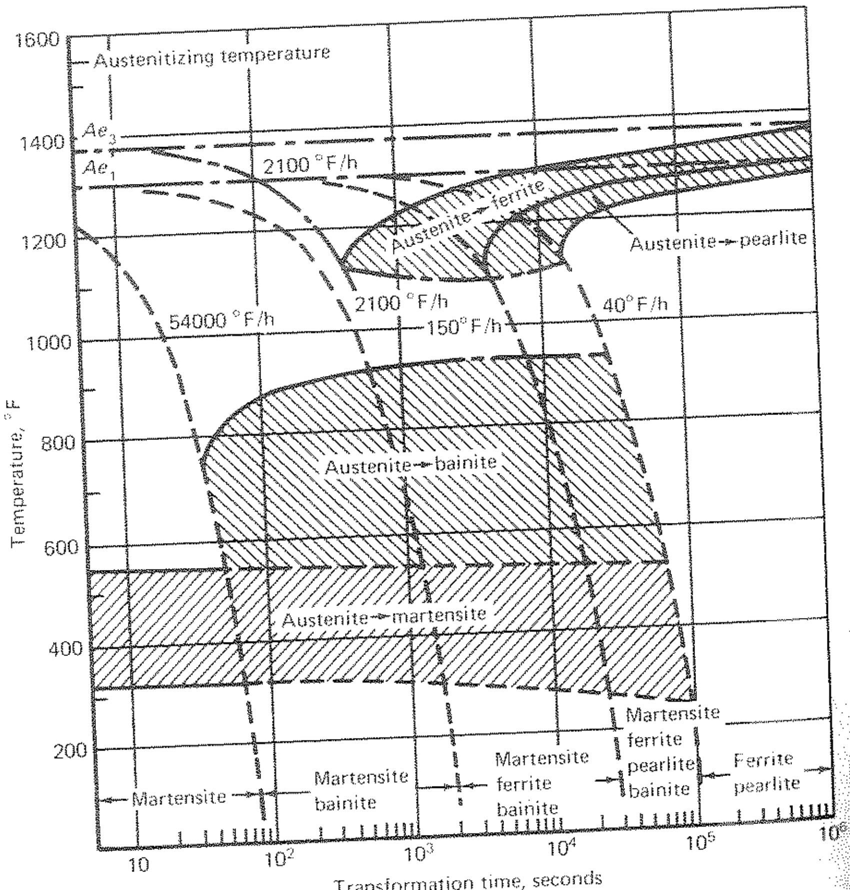
ected zone are cooled too fast, they will rm to martensite or a combination of mar- and bainite, as illustrated in Fig. 1.10 for 340 steel. The internal stresses that de- uring cooling from both the contraction weld and heat-affected zone and the trans- ion of austenite may cause hard martensite k. Steels in this group are very sensitive rogen-induced cracking. Therefore, the g process and procedures should minimize esence of hydrogen during welding as well formation of martensite.

he best approach to welding these steels reheat the joint area to 600°F or higher so he cooling rate of the weld will be slow h to form softer bainite in preference to martensite. A bainitic microstructure in the weld and heat-affected zone will have sufficient toughness to permit intermediate handling between welding and postweld heat treatment.

In some applications, a practical preheat temperature may be too low for complete transformation to bainite. Then, the weld and heat-affected zone may contain some martensite and retained austenite. Appropriate postweld operations are necessary to transform the austenite to martensite or bainite, depending upon the intermediate processing prior to hardening.

PREHEAT

The minimum preheat and interpass temperature required to prevent cracking with a given steel depends on



(1) Its carbon and alloy content
(2) Condition of heat treatment
(3) Section thickness or amount of restraint on the joint
(4) Available hydrogen during welding

A change in process or procedures to reduce available hydrogen or a decrease in thicknesses or joint restraint may permit the use of a lower preheat temperature.

The ideal preheat temperature is about 50°F above the temperature at which martensite starts to form on cooling (M_s). Holding at this temperature for a time after welding will produce a bainitic structure in the weld and heat-affected zones. It will also permit dissolved hydrogen to escape from thin sections. The volumetric expansion that takes place during transformation will not produce localized peak stresses at this preheat temperature that lead to cracking.

However, the M_s temperature of many of the HTLA steels is above 500°F. A preheat temperature of 550°F or higher will contribute to welder discomfort and promote the formation of a thin oxide layer on the joint faces. Such oxidation may cause unacceptable discontinuities in the weld. Consequently, a welding process that permits the use of a lower preheat temperature should be used when practical. Otherwise, the welding process and procedures must be designed to minimize the problems associated with a high preheat temperature. Some low alloy steels with high carbon content will require high preheat and interpass temperatures with low hydrogen welding processes. Recommended minimum preheat and interpass temperatures for several AISI low alloy steels are given in Table 1.26.

Table 1.26
Recommended minimum preheat and interpass temperatures for several AISI low alloy steels

AISI steel	Thickness range, in.	Minimum preheat and interpass temperature, °F[a]
4027	Up to 0.5	50
	0.6–1.0	150
	1.1–2.0	250
4037	Up to 0.5	100
	0.6–1.0	200
	1.1–2.0	300
4130, 5140	Up to 0.5	300
	0.6–1.0	400
	1.1–2.0	450
4135, 4140	Up to 0.5	350
	0.6–1.0	450
	1.1–2.0	500
4320, 5130	Up to 0.5	200
	0.6–1.0	300
	1.1–2.0	400
4340	Up to 2.0	550
8630	Up to 0.5	200
	0.6–1.0	250
	1.1–2.0	300
8640	Up to 0.5	200
	0.6–1.0	300
	1.1–2.0	350
8740	Up to 1.0	300
	1.1–2.0	400