I. INTRODUCTION

The evolution of the aircraft gas turbines has involved the development of complex materials capable of maintaining certain of their room-temperature physical and mechanical properties at elevated temperatures. Austenitic superalloys-iron, cobalt or nickel-base have been and are being used in gas turbines.

The purpose of the present paper is to develop and discuss the relations between microstructures and resulting mechanical properties in superalloys. Considering the demand for longer lives in aircraft turbines, which is also a requirement for the development of industrial turbines, the understanding of microstructural property interactions is of first importance to optimize the mechanical properties stability of superalloys.

The present paper is not intended to be an exhaustive summary of the effects microstructure can have on mechanical properties; some papers have reviewed in detail the microstructures and their effects on mechanical properties in nickel as well as cobalt-base superalloys (1 to 11).
Rather, it is planned to review the major hardening mechanisme used in modern superalloys. It will be then possible to describe the microstructural modifications involved by each hardening mechanism and to illustrate their effects on the mechanical properties. The discussion will be restricted to nickel and cobalt-base superalloys, the evolution of which has closely paralleled that of the aircraft gas turbines. The microstructural property interactions will be illustrated for different representative wrought as well as cast superalloys.

II. GENERAL BACKGROUND.

Nickel and cobalt-base superalloys contain a variety of elements in a large number of combinations to accomplish one or more specific purposes.

Some elements go into solid solution namely either to provide strength (molybdenum and tungsten) or oxidation resistance (chromium). Recently, a few alloys have been developed for special purposes, such as for aerospace applications that contain little or no chromium. Other elements are added to form intermetallic compounds (aluminium, titanium, niobium) or carbides; some elements that are known to participate actively in carbide formation are : niobium, tantalum, tungsten, molybdenum, chromium, zirconium and titanium. In addition to the carbides, boron and zirconium have been found to increase the rupture life of nickel and cobalt-base alloys when added in small amounts. Table I summarizes some effects of various elements.

For most nickel-base superalloys, the ordered intermetallic face centered-cubic γ' phase Ni_3 (Al, Ti, Nb) is responsible for the useful high-temperature properties. The γ' precipitate is unique in that its strength increases with temperature up to about 760°C (1400°F) (12). Cobalt is also added to decrease the solubility of elements which form the γ'-phase. Strengthening by γ' precipitation requires some form of heat treatment in order to optimize the particular properties required. Carbides are also an important constituent in nickel-based alloys.

Cobalt-base superalloys commonly are hardened by a combination of carbide formation and solid solution(6), with the former being more important. Strengthening by ordered intermetallic phase precipitation has also been exploited in cobalt-base superalloys (7).

It must be said that cobalt is an allotrope element, transforming from the hexagonal close-packed (HCP) to the face-centered cubic (FCC) form at 785°F (417°C) upon heating. However, similarly to nickel-base superalloys, most cobalt alloys are FCC in structure even at room temperature since some of the alloying elements commonly added, namely nickel, stabilize the FCC matrix.