



## Seminar Outline

# Gear Materials: Selection, Metallurgy, Heat Treatment, and Quality Control

Instructors: Raymond J. Drago, P.E.,  
Chief Engineer & Roy J. Cunningham,  
Senior Metallurgist, Drive Systems  
Technology, Inc

While we will address a range of heat treatment processes in the general sense, since carburized gears are used in a great many critical applications, we will address this processing methodology, in particular, in great detail. Some of the topics to be discussed are:

1. Initial gear material selection – What are the advantages and disadvantages of the various gear material choices including steel, cast iron, ductile iron, plastics, bronze, and more exotic choices?
2. Heat treatment processes and their relation to gear performance, cost, reliability, and load characteristics – Through hardening before and after tooth cutting, nitriding, various types of induction hardening (including coil, tooth-by-tooth, dual and multiple frequency) carbo-nitriding, and various types of carburizing will be addressed in order to relate the properties obtained to the needs of the gear system.
3. Engineering drawing development – The best material selection process is only as good as the engineering drawing's ability to define and control the process in an unambiguous, clear and complete manner. The need for certification of material properties, heat treatment results and quality control of the overall process will be addressed using examples of proper drawing practice.
4. Review of the engineering drawing – what should the metallurgist look for – five important areas – material, part configuration, heat treat requirements, surface finish technique and quality control requirements.
5. Understanding melt processing – types and quality level – effects of various elements such as sulfur and phosphorus, hydrogen content, inclusion content, work ratio, normalizing, residual stress considerations. Inspection techniques and advantages – ultrasonic and magnetic particle.
6. Gear materials – their nomenclature, what makes steel steel, effects of the elements, is stainless really stainless? Typical heat treatment processing technique for gear materials.
7. What is carburizing? How does it occur? Comparison of various processes, how to optimize the cycle.
8. What is stress relieving, hardening, quenching, tempering, and deep freezing? Enhancements such as methods to control distortion, intergranular oxidation (IGO) and decarburization.
8. Why the metallurgist should review of the manufacturing process sequence – what he should look for. What about the welding process used for big parts? Review of the heat treat configuration of the part – what is important at this point in the cycle? When and when not to inspect. What about corrosion – can it occur in the shop? How can it be prevented?
9. The metallurgical review of the heat treat facility and the laboratory. The type of furnace, the carburizing atmosphere and its control should be understood. How to inspect and insure uniformity of both temperature and carburizing gases is maintained during the heat treat cycle. What equipment is needed in every metallurgical laboratory from a test sample standpoint?
10. Control of the heat treat process during the actual cycle. How does the metallurgist insure effective carburizing will occur? The use of test slugs, their size and placement. Where and how does distortion occur? What about decarburization, intergranular oxidation, temper embrittlement. The heat treat procedure should be understood to minimize there.
11. Metallurgical heat treat test sample preparation and evaluation techniques to insure the data is relevant to the actual parts. Sample and preparation techniques. What to do and not to do. What to look for – intergranular oxidation (IGO) causes and effects, decarburization, retained austenite, how much is OK, etc. Microhardness evaluations and their comparison to the microstructure observed can be used to denote the effectiveness of the overall carburizing process. What about carbides? Are they bad or good?
12. Final inspection and finishing of the gear – This section will include a discussion on the types of grinding burns and how to prevent them from occurring. Other inspection techniques such as magnetic particle, ultrasonic, eddy current will be detailed. Finally, shot peening, the process and its benefits will be discussed.