SAWYER'S GAS TURBINE ENGINEERING HANDBOOK

Third Edition
Three Volumes

VOLUME III
ACCESSORIES & SUPPORT

TURBOMACHINERY INTERNATIONAL PUBLICATIONS

SAWYER'S
GAS TURBINE ENGINEERING HANDBOOK

Third Edition

Volume III of Three Volumes

- I Theory & Design
- II Selection & Application
- III Accessories & Support

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PREFACE

This new edition has been written for those in the gas turbine field who are concerned with research, design, manufacture, selection, application, evaluation, teaching, training, marketing, and related activities. It is a comprehensive work that consists of 41 chapters, with contributions from 57 authors. These individuals are recognized authorities from a number of countries. They represent universities, research organizations, manufacturers, users, government, training establishments, and consultants.

The book is to serve as a reference, text, and specific guide for people in the many areas of gas turbine endeavor. The designer, engineer, manufacturer, user, selector of equipment, instructor, student, researcher, and others will find it of considerable help.

The gas turbine field is broad and highly technical, thus it is not feasible for a single author to put together a reference work with the vast scope and technical depth presented here. For this reason it has been necessary to bring together a number of authorities from the many areas of gas turbine technology to write this book.

Volume I concerns thermodynamics and fundamentals; cycle variations and calculations; aerodynamic design of compressors and turbines; combustor design; bearing design; structural design and analysis; computers in design and testing, and preliminary and detailed design of the complete gas turbine engine.

Volume II deals with selection and application of gas turbines in the major fields of use. These include: electric power generation; pipeline industry; marine, ships; offshore; cogeneration; cryogenics refrigeration and power recovery; combined cycles; legislation and regulations; economic evaluation; calculation and performance adjustment for on site conditions; maintainability, and the market.

Volume III covers materials, fuels, and treatment; controls; instruments, accessories, and internal systems; heat exchangers; inlet air filtration; noise control, ISO Standard testing and measuring tolerances; U.S. Standards; monitoring and control; fundamentals of energy exchange in the turbine; training, and quality assurance.

A comprehensive subject index for the entire book is incorporated into each volume. This provides a detailed source of the subject matter contained in the book. It is cross-referenced where appropriate.

It is appreciated that a single book cannot give comprehensive coverage to every topic in this highly technical field. In order to provide additional reference sources, extensive bibliographies have been included with a number of the more involved chapters. In addition to the bibliographies, references are listed in many chapters to offer greater detail on specific subjects under discussion.

Since the second edition was published in 1972, thirteen years ago, the developments of gas turbines have been extremely significant. The improvements include materials, component efficiencies, higher operating temperatures, design methods involving use of computers, new manufacturing techniques, instrumentation, and new industrial uses for the gas turbine.

The number of gas turbines in use and also the number and types of applications have increased greatly during the past decade. This has resulted in impressive growth in the number of people involved in manufacturing, design, marketing, selection, operation, inspection, maintenance, development, education, and training.

In summary the rapid development in the past thirteen years has been such that it was considered essential to prepare this third edition to provide an all inclusive update on this prime mover. The gas turbine community will find this book to be a valuable reference.

ACKNOWLEDGMENTS

This, the third edition, is a tribute to the authors and their organizations for their contribution of many thousands of manhours in researching and preparing this updated and outstanding treatise on gas turbine engineering. It is a timely and valuable technical addition to this engineering field. The authors' efforts are recognized and deeply appreciated.

Sincere thanks are extended to my many colleagues who so kindly debated both the subject matter and its manner of presentation in the book.

It has been my pleasure to have worked with Mr. G. Renfrew Brighton, Chairman of the Board, Business Journals, Inc., for 25 years on gas turbine publications, including magazines, catalogs, and handbooks. Since 1966 he has given me encouragement and support in the preparation and publication of ten volumes of engineering handbooks, including this three volume, third edition, of Sawyer's Gas Turbine Engineering Handbook.

Dr. David Japikse, Associate Editor of this handbook, provided technical expertise in many cases. He was also instrumental in developing content and modifications in the book. In addition, Dr. Japikse authored a number of important chapters for this edition. Members of his staff including Helen D. Tucker, Marguerite B. Bradshaw and Sharon E. Wight did outstanding work in typesetting, layout, and proofreading the material in these volumes.

The assistance of Kurt Hallberg, Director/Publisher, Turbomachinery International, and Frances Salamon, Director of Manufacturing and Production, Business Journals, Inc., was invaluable.

I want to recognize the following outstanding and dedicated educators: Professor William Hand Browne, Jr. (deceased), former Head of the Department of Electrical Engineering, North Carolina State College; Professor F. W. Marquis (deceased), former Head of the Department of Mechanical Engineering, Ohio State University; and Miss Dama Hill, my former teacher and long time friend.

To my wife, Dorothy Uhl Sawyer, I am sincerely grateful for her valuable help, understanding, and encouragement throughout the four years this book was in preparation.

John W. Sawyer
January 1985

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CHAPTER
1

MATERIALS FOR HEAVY DUTY INDUSTRIAL GAS TURBINES

by Scott T. Scheirer and David M. Moon

CONTENTS

1.0 INTRODUCTION

The gas turbine is a complex machine requiring the contributions of various engineering disciplines to harness aerodynamic, thermal, and mechanical forces and perform useful work. The technology has been evolutionary, introducing new designs for improved performance without sacrificing the reliability which operators demand. The materials and methods of construction have followed a similar evolutionary path. Initially, available stainless steels were utilized for hot parts; and then, gradually, an entire high temperature alloy industry was developed, built around nickel- and cobalt-base materials. Figure 1, a schematic representation of today's industrial gas turbine and approximate gas temperatures, illustrates why a great variety of materials is necessary for the entire engine. Methods of manufacture have also been in step with design requirements; the evolution of the precision investment casting industry being an outstanding example. Looking to the future one can anticipate an even closer linking between design requirements, materials, and methods of construction. Techniques like diffusion bonding, directional solidification, and powder metallurgy will enable the use of materials with specialized properties. The designer can then tailor-make various components for maximum effectiveness.

There are a number of factors, both operational as well as design related, which assume relatively greater importance in land-based industrial gas turbines compared to aircraft engines. Because of this, unique problems exist which prevent the direct transfer of aircraft engine materials technology to their land-based cousins. In some cases the job is simplified; for example, since the overall weight restriction is much less severe, there is little justifiable need for the strong and light but costly titanium alloys in the compressor. In the turbine, requirements for strength retention of blading materials at high take-off power temperatures is replaced by the need for creep resistance at more moderate temperatures over very long operating periods. Land-based turbine blading materials must have a high degree of corrosion resistance to combat the damaging effects of a variety of fuel impurities, thereby imparting fuel flexibility to the turbine design. Modern industrial gas turbines are called upon to burn a wide range of fuels from natural gas to residual and crude oil and coal derivatives. Protective coatings are applied to guard against hot corrosion due to aggressive impurity deposits rather than high temperature gas phase oxidation as is more likely to be encountered in aircraft engines.

The large size of land-based turbine components is more often than not a detriment when compared to aircraft engine parts, Fig. 2. Forged last row blades severely tax the capacity of existing forge presses. A high temperature nickel alloy poured into molds for industrial gas turbine blades encounters a much wider range of solidification conditions than does the same alloy in an aircraft engine sized part. Consequently, the number of alloys available for land-based engine blades which can be successfully cast with acceptable porosity levels and grain structures is considerably reduced. Size is also a factor which limits the introduction of some newer technologies, such as powder metallurgy, composites, directional solidification, and electron beam welding. Where special benefits are

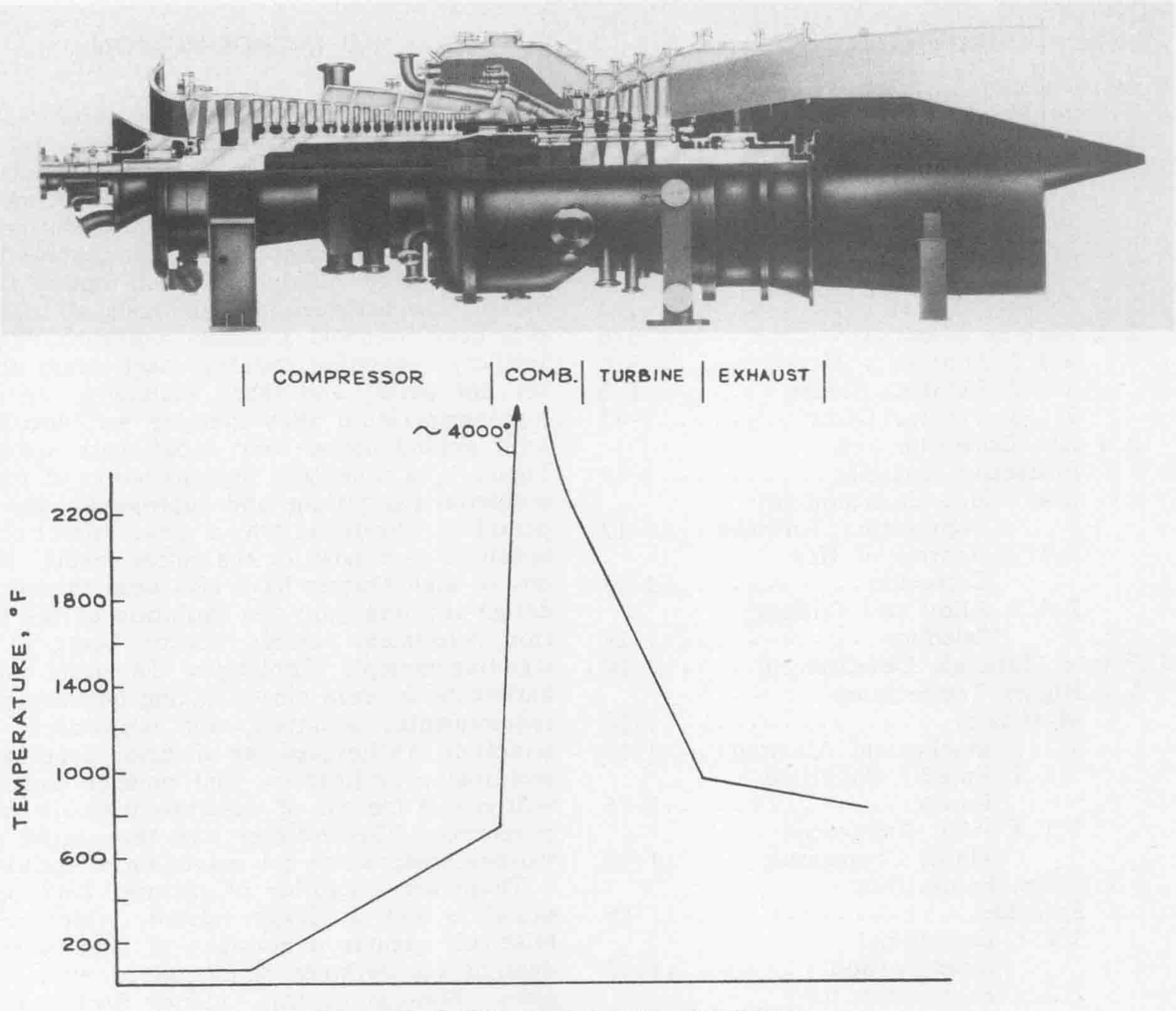

Figure 1. Schematic of Industrial Gas Turbine Showing Nominal Gas Temperatures

expected, these advanced technologies are being introduced in industrial gas turbines, as discussed in a later section of this chapter.

2.0 PRESENT MATERIAL UTILIZATION

2.1 Compressor Materials

The compressor of the modern industrial combustion turbine represents relatively low temperature material requirements. Alloys used are generally conventional and, in most cases, were first developed for other applications. The maximum temperatures achieved depend upon compression ratio but are generally not over 750°F. As a result, there is little need for high temperature creep resistant nickel- and cobalt-base materials; carbon steel, low alloy steels, and hardenable stainless steels of the 12% chromium type are quite satisfactory. Important components which will be discussed are the casing, discs and shafts, rotating blades, and vanes. Materials commonly used in the manufacture of these components are listed in Table 1.

2.1.1 Casings

The casings for industrial combustion turbines may seem to be a low technology item. They are large sand castings, or fabrications, often made in carbon steel, or occasionally, cast or nodular iron. The fabrications are built up by welding plate or smaller castings into large objects sometimes weighing over 20,000 pounds. The casing components are generally separated along a horizontal plane passing through the turbine axis. These casings, compressor, combustor, and turbine alike are in essence pressure vessels. Therefore, the design is often developed according to the requirements of the ASME (American Society of Mechanical Engineers) Pressure Vessel Code. Materials and welding methods are selected on that basis. Tensile and creep strength up to about 750°F with good fracture toughness

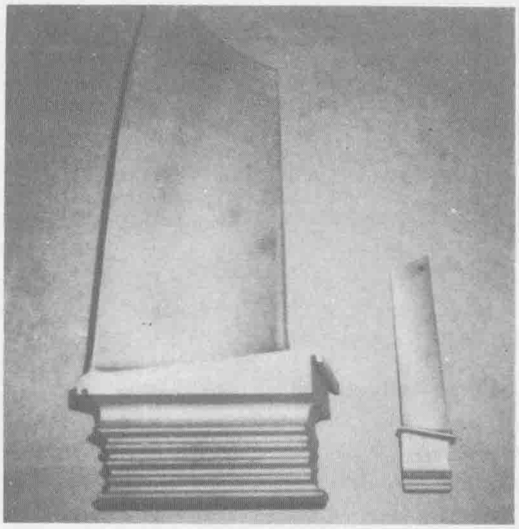

Figure 2. Comparison of Turbine Blades for Aircraft and Industrial Gas Turbines

Table 1. Use of Iron-Base Alloys in Industrial Gas Turbines

Component	Alloy	Nominal Composition
Casing- Inlet, Compressor, and Combustor	Carbon Steel Plate (e.g. A-515 Gr.70)	Fe-0.3C-0.75Mn-0.25Si
	Carbon Steel Casting (e.g. A-356 Gr.1)	Fe-0.3C-0.8Mn-0.5Si
	Cast Iron (e.g. A-278)	Fe-3.8 Total C Max.
- Turbine	Low Alloy Steel Plate (e.g. A-387 Gr.22)	Fe-2.25Cr-1.0Mo-0.15C
	Low Alloy Steel Castings (e.g. A-217 Gr.WC9)	Fe-2.25Cr-1.0Mo-o.15C
	Nodular Iron (e.g. A-395)	Fe-3.0 Total C Min.-2.5Si
Compressor Blades	AISI Type 403	Fe-12Cr-0.12C
Compressor Vanes	AISI Type 403	Fe-12Cr-0.12C
	Low Alloy Steels	
Discs- Compressor	CrMo (AISI-4140)	Fe-1.0Cr-0.2Mo-0.4C
	NiCrMo (AISI-4340)	Fe-2.0Ni-0.75Cr-0.25Mo-0.4C
	CrMoV (e.g. A-471 Gr.10)	Fe-1.2Cr-1.15M0-0.25V-0.3C
	Super 12 Chrome Steels	
	AISI Type 422	Fe-0.5Ni-12Cr-1.1Mo-0.3V-1.1W-0.75Mn-0.5Si-0.25C
	FV535	Fe-0.5Ni-6.0Co-11.0Cr-0.75Mo-0.25V-0.4Cb-0.9Mn-0.5Si-0.09C
	Low Alloy Steels (Sim. to A471)	
- Turbine	NiCrMoV	Fe-3.5Ni-1.75Cr-0.5Mo-0.1V-0.35C
	CrMoV	Fe-1.2Cr-1.15Mo-0.25V-0.3C
	Iron Base Superalloys	
	Discalloy	Fe-26Ni-13.5Cr-2.75Mo-1.75Ti-0.1Al-0.04C-0.9Mn
	A-286	Fe-26Ni-15Cr-1.25Mo-0.3V-2.15Ti-0.2Al-0.05C-1.4 Mn
Turbine Vanes (Back Stages)	Multimet (N-155)	Fe-20Ni-20Co-21Cr-3Mo-2.5W-1Cb-0.15C-1.5Mn
	AISI Type 310	Fe-20Ni-25Cr-0.1C

throughout the range are necessities for casings. For the exhaust casing where slightly higher temperatures are encountered, a low alloy steel such as 2-1/4% chromium - 1% molybdenum is used in the quenched and tempered condition in order to satisfy the demands of this application.

2.1.2 Compressor Forgings (Discs and Shafts)

The compressor blades are carried on a series of high strength forged discs which, depending upon the turbine design, may be shrunk on a forged shaft, and welded or bolted together. High strength hardenable steel forgings which are modifications of the AISI 4100 and 4300 types (Cr-Mo-V and Ni-Cr-Mo-V) are workhorse alloys for these large disc forgings which may be as much as 50 inches in diameter and weigh over 2000 pounds each. The property requirements for compressor discs vary slightly as a function of design details but include as a minimum; high tensile yield and ultimate strength at temperatures approaching 750°F, resistance to creep relaxation, and good fracture toughness at ambient temperature conditions as well as operating temperatures. In newer compressors where compression ratios are higher, temperature considerations require the use of alloys of the super 12% chromium class, (e.g. FV535, and Type 422 stainless steel) for latter stages.

Careful attention to processing details helps to ensure that the Ni-Cr-Mo-V and Cr-Mo-V steels maintain a low impurity content. Low levels of sulfur and phosphorous permit the attainment of a high strength, tempered, lower bainite microstructure having high toughness. Air melting with vacuum degassing and forging by open or closed die methods help to insure high quality, low-defect discs. Vacuum arc or electro-slag remelting techniques are used for the 12% Cr class of alloy discs. A double temper heat treatment is also employed to help obtain the desired uniform properties.

Nondestructive inspection of compressor discs has become an integral part of the design process. Magnetic particle and immersion ultrasonic methods are used to insure that surface and internal flaws and material discontinuities which could grow in service are not present in the finished product. Processing methods today are such that very few disc forgings are rejected, even with the stringent standards dictated by fracture toughness and crack growth mechanics models.

Industrial turbines which are in more or less continuous duty do not experience any rusting or corrosion problems in the compressor. For those operators who contemplate long-term storage or frequent and extended down periods, especially in humid climates, corrosion retarding coatings can be applied to exposed areas of the discs. Aluminum filled coatings with an organic binder have been successfully used to provide sacrificial protection.

2.1.3 Compressor Blades and Vanes

Compressor stationary vanes and rotating blades are generally fabricated from a heat treatable 12% chromium stainless steel, such as Type 403 or 410. This class of alloy provides the tensile strength at ambient temperatures and the strength retention and creep resistance needed for the entire temperature range of compressor airfoil service, up to about 800°F. Other qualities of this class of alloy which are attractive for the compressor blading applications include; toughness and resistance to impact caused by foreign objects, good mechanical damping, and resistance to atmospheric corrosion in a variety of environments.

Rotating blades are either precision forged or machined with very thin leading and trailing edges for aerodynamic efficiency. The stationary vane airfoils may be produced as individual pieces like the blades or they may be assembled into multiple vane segments of up to 180 degrees. In the latter case the airfoils are either forged, machined, or cut to length from form rolled bar. They are then assembled into segments and welded to curved shroud strips. The good weldability of the 403 stainless is a property which is central to this manufacturing technique. Some compressor stationary vanes are produced as precision castings containing several airfoils in a single segment of approximately 30 to 60 degrees, Fig. 3.

Corrosion of the compressor airfoils is not generally a problem unless the turbine is operated intermittently in humid climates or endures periods of extended storage. Since compressor efficiency is significantly affected by airfoil surface roughness, some users, faced with the possibility of corrosion, elect to apply a protective coating to the blades and vanes. Aluminum rich sacrificial coatings have proven effective for this purpose. They may be applied either by a sprayed slurry followed by a low temperature bake or by a diffusion process. In the second case, care must be taken to insure that the coating application temperatures do not adversely affect the temper condition of the base alloy. Other types of coatings have also been used with varying degrees of success. These include Teflon® and nickel-cadmium plating.

2.2 Combustors

The combustion system in an industrial combustion turbine basically consists of a combustion chamber, or chambers, and ducting which directs the hot gases into the first stage guide vanes of the turbine. A representative design is shown in Fig. 4. In the most popular design, a number of combustor baskets (cans or liners) are arranged in an annular fashion around the axis of the turbine. Compressor discharge air is mixed with fuel and combusted near the neck of the basket. The basket is designed to contain the flame, mix in diluent air, control temperature emissions and smoke, channel the hot gases into the turbine, and provide for air cooling of the metal walls.

For this type of service, the materials chosen must be capable of strength retention at moderate temperature, possess oxidation and carburization resistance, maintain metallurgical stability in service to avoid embrittlement, and be fabricable and weldable in sheet form, both for initial manufacture and for ease of repairing service induced defects.

An adequate cooling design is essential to prevent excessive radiant heating of the basket walls. If this is done and adequate fuel nozzle maintenance is performed to prevent flame impingement, several years of satisfactory service can be obtained from the basket material.

Typical alloys used for industrial gas turbine combustors and transition ducts are listed in Table 2. The austenitic grades of stainless steel (e.g. Type 310) were initially chosen for combustor baskets and are still being used successfully. Higher firing temperature turbines have generally employed nickel or cobalt alloy sheet; Hastelloy X and Haynes Alloy 188 being popular choices. For improved creep strength retention, alloys such as Inconel 617 and 625 are being used for some of the most recent designs. Nominal stress rupture properties for some sheet alloys are shown in Fig. 5. Whereas Hastelloy X is usually used in the solution annealed condition, some of the higher strength alloys require additional aging heat treatments to develop full strength potential. Care must be exercised not to select alloys which, because of their complex physical metallurgy, are difficult to weld or are unstable in service. When the later condition occurs, service aging can result in the

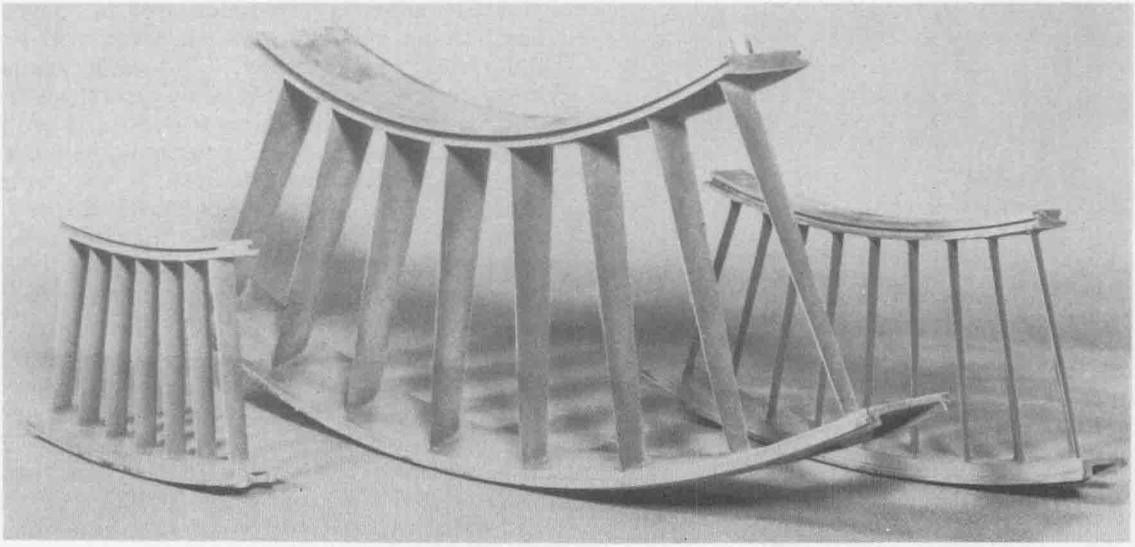

Figure 3. Cast 12% Chromium Steel Compressor Vane Segment

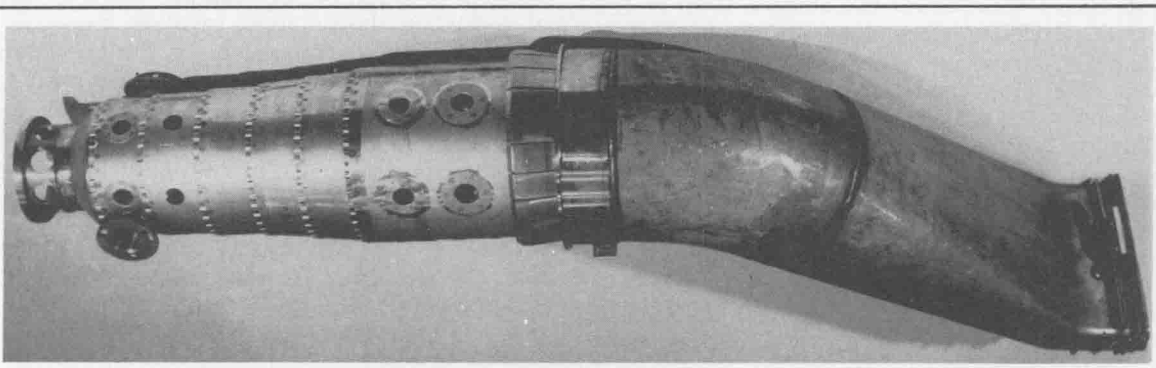

Figure 4. Combustor Basket and Transition, Hastelloy X

Table 2. Superalloy Sheet Materials Used for Industrial Gas Turbine Combustors and Transitions

Nickel Base	Ni	Fe	Co	Cr	Mo	W	Al	Ti	C	Other
Hastelloy X	Bal	18.5	1.5	22.0	9.0	0.6	-	-	0.10	-
Inconel 617	Bal	1.5	12.5	22.0	9.0	-	1.2	0.3	0.10	0.2 Cu
Inconel 625	Bal	2.5	-	21.5	9.0	-	0.2	0.3	0.05	3.6 Cb
Nimonic C-263	Bal	-	20.5	20.0	5.9	-	0.5	2.2	0.06	-
Cobalt Base										
Haynes Alloy 188	22.0	1.5	Bal	22.0	-	14.0	-	-	0.1	0.07 La
Iron Base										
AISI Type 310	20.0	Bal	-	25.0	-	-	-	-	0.1	-

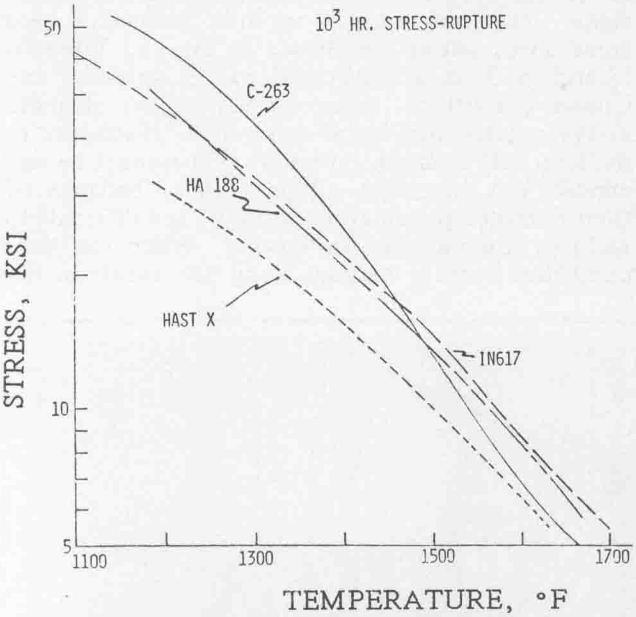

Figure 5. Stress-Rupture Properties of Combustor Sheet Alloys

formation of an embrittled microstructure.

Fabrication of combustor baskets requires cold forming of the sheet, TIG welding, and spot welding. In some cases, brazing is used to augment the spot welds. Dimensional accuracy is especially important so that proper alignment can be achieved upon installation.

Transition ducts are fabricated from the same class of alloys (and often the same alloy) as the combustor baskets. The property requirements are quite similar as are the fabrication methods. Coatings are sometimes applied to combustor baskets and transition ducts. Aluminides or other diffusion type coatings can be used for protection against corrosion and oxidation. Some coatings of this type are applied by spraying a slurry which is then dried and later diffused at high temperature, either in a heat treating furnace or by relying on the radiant heating of the hot gases during normal operation. Ceramic thermal barrier coatings, such as stabilized zirconia, have been used to reduce metal wall heating due to radiation. These coatings are applied by plasma spray and consist of at least two layers; a thin sprayed metallic bond coat to metallurgically adhere to the basket inner wall and a thicker (0.005" to 0.015") ceramic insulating layer. Thermal barrier coatings of this type have great potential for higher temperature combustion turbines but must first overcome problems of poor thermal shock, low cycle fatigue resistance, and susceptibility to attack by contaminants found in some heavy fuels (especially vanadium and sodium).

Advanced oxide dispersion strengthened (ODS) materials now being used in some aircraft combustion systems may be introduced in future industrial gas turbines. The high temperature creep resistance of ODS alloys is very attractive, but they present problems for fabrication by conventional fusion welding techniques because of the agglomeration of oxides in the overheated zone and the accompanying strength loss. Diffusion bonding, brazing, and mechanical joining are possibilities.

2.3 Turbine Materials

It is in the turbine section of the industrial combustion turbine where the high temperature superalloy industry finds a home. Rotating blades and stationary vanes are subjected to high stresses, gas temperatures exceeding 2000°F, large thermal gradients and thermal transients, unavoidable vibratory loadings due to gas forces, and oxidizing and corroding environments. These conditions are in effect for aircraft gas turbines as well as land-based designs, but the large size of industrial land-based turbines imposes a significant additional problem on the precision forging and casting processes which are used to produce turbine blades and vanes. Vane segment castings can weigh as much as 150 pounds, and some have intricate cast-in internal cooling air passages. Forged blades approach 2-1/2 feet in length. With these sorts of restraints it is not surprising that alloy and process development have paced the growth of industrial turbine technology.

2.3.1 Stationary Vanes

The first stage turbine inlet guide vanes must perform the function of turning and directing the flow of hot gas into the rotating stage of the turbine at the most favorable angle of incidence. They are literally right in the line of fire; routinely being subjected to impingement of the highest temperature gases and experiencing the highest metal temperatures of any component in the turbine. Even though the superalloys used for vanes are capable of creep resistance at temperatures above 1700°F for short periods in aircraft engine applications, the desire for component lifetimes of 50,000 to 100,000 hours for industrial turbine vanes means that a high degree of cooling is necessary for the required creep life and oxidation/corrosion resistance.

Although there are no centrifugal stresses on the vanes, the combination of gas bending loads and the thermal gradients caused by the vane cooling result in rather high localized steady state operating stresses in stationary vanes. Thermal stresses due to uneven heating and cooling of leading and trailing edges during starting and shutdown are also a factor and can cause airfoil cracking at these locations. The critical mechanical property attributes which a vane alloy must possess are creep strength to resist airfoil distortion due to gas loading and thermal stresses, low cycle fatigue strength to resist the thermal strains, and oxidation/corrosion resistance.

Material selection integrates advanced metallurgical concepts of alloy strengthening and material processing with the requirements of mechanical design and heat transfer. It is common to use the most advanced, highest strength alloy available for the highly cooled first stage vanes. The design of the later stage vanes becomes a balance of two factors, alloy strength and amount of cooling. In some cases, the choice is for high strength alloys with little or no cooling, whereas in other cases where moderate levels of cooling are used lower strength alloys with greater castability are chosen.

Most stationary vanes used for currently built industrial gas turbines are single or multiple airfoil investment castings made from a cobalt-base alloy. In addition to the mechanical property requirements already discussed, the material must be easily cast in the large (up to 150 pounds), complex (internal cooling passages) configurations. The alloy must also be weldable for ease of fabrication (cooling inserts are welded in place) and for repair of service induced damage. The most popular vane alloys currently in use are Haynes Stellite Alloy No. 31 (X-40) and its lower carbon relative X-45, Table 3. These alloys are both precision cast in air as is a higher chromium derivative of X-40, called FSX-414. The highest strength cobalt alloy currently in use for industrial turbine vanes is vacuum cast ECY-768, an alloy developed to retain the creep resistance of MarM509 while improving castability. This was primarily accomplished by reducing the zirconium content of MarM509 to prevent a mold wall reaction which caused surface oxides in large massive castings. This effect does not occur in the smaller aircraft engine vane castings which cool much more rapidly. Stress rupture properties for these cobalt-base turbine vane alloys are shown in Fig. 6.

The cobalt-base alloys described are solid solution strengthened by the addition of the refractory metal elements tungsten and tantalum and by the formation of carbides of chromium and zirconium. Chromium is also important for the oxidation and corrosion resistance it imparts. The alloys are generally used in the as-cast condition or with an abbreviated heat treatment consisting of a solution treatment followed by an aging treatment to stabilize carbides. Occasionally, fabrication processes such as brazing are incorporated into the heat treatment to secure the cooling inserts.

Cast nickel-base alloys, see Table 4, such as Udimet 500, IN-738, and IN-939, which are generally associated with turbine rotating blades, have been used for some stationary vanes. However, since it is difficult to produce blade quality castings in large multi-vane segments, the nickel-base alloys have been used for single airfoil castings. In some cooler running machines where vanes are uncooled, the cast nickel alloy airfoils (typically U-500) are welded to shrouds which may be either an

Table 3. Nominal Compositions of Selected Alloys Used for Industrial Gas Turbine Vanes

Cobalt Base	Co	Ni	Fe	Cr	Mo	W	Ta	Al	Ti	C	B	Zr
X-40 (Stellite 31)	Bal	10.0	1.5	25.0	-	7.5	-	-	-	0.5	-	-
X-45	Bal	10.5	2.0	25.5	-	7.0	-	-	-	0.25	0.01	-
FSX-414	Bal	10.5	2.0	29.5	-	7.0	-	-	-	0.25	0.012	-
Mar M 509	Bal	10.0	1.0	21.5	-	7.0	3.5	-	0.2	0.60	0.01	0.5
ECY-768	Bal	10.0	1.0	23.5	-	7.0	3.5	0.15	0.2	0.60	0.01	0.05
Iron Base												
Multimet N-155	20.0	20.0	Bal	21.0	3.0	2.5	1.0Cb	-	-	0.15	-	-
AISI Type 310	-	20.0	Bal	25.0	-	-	-	-	-	0.1	-	-