

**ANNA UNIVERSITY - COIMBATORE – 13  
CURRICULUM - 2007  
POST GRADUATE PROGRAMME  
Branch : M.E. (WELDING TECHNOLOGY)**

**SEMESTER – I (FULL- TIME)**

<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
<b>THEORY</b>					
07WT101	Probability and Statistics	3	1	0	100
07WT102	Conventional Welding Processes	3	1	0	100
07WT103	Electrical Aspects of Welding	3	0	0	100
07WT104	Materials Technology	3	0	0	100
07WTEXX	Elective I	3	0	0	100
07WTEXX	Elective II	3	0	0	100
<b>PRACTICALS</b>					
07WT105	Advanced Metallography Lab	0	0	3	100
	<b>TOTAL</b>	<b>18</b>	<b>2</b>	<b>3</b>	<b>700</b>

**SEMESTER – II (FULL- TIME)**

<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
<b>THEORY</b>					
07WT201	Mechanical Behaviour of Materials	3	1	0	100
07WT202	Welding Metallurgy	3	0	0	100
07WT203	Quality Control of Weldments	3	0	0	100
07WT204	Advanced Welding Processes	3	0	0	100
07WTEXX	Elective III	3	0	0	100
07WTEXX	Elective IV	3	0	0	100
<b>PRACTICALS</b>					
07WT205	Technical Seminar (Internal Evaluation Only)	0	0	3	100
07WT206	Welding Metallurgy Lab	0	0	3	100
	<b>TOTAL</b>	<b>18</b>	<b>1</b>	<b>6</b>	<b>800</b>

**SEMESTER – III (FULL- TIME)**

<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
<b>THEORY</b>					
07WT301	Design of Weldments and Failure Analysis	3	0	0	100
07WTEXX	Elective – V	3	0	0	100
07WTEXX	Elective – VI	3	0	0	100
<b>PRACTICALS</b>					
07WT302	Project Work Phase I	0	0	12	200
07WT303	Practical Training (4 weeks) (In previous vacation)	0	0	0	100
<b>TOTAL</b>		<b>9</b>	<b>0</b>	<b>12</b>	<b>600</b>

**SEMESTER – IV (FULL- TIME)**

<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
<b>PRACTICALS</b>					
07WT401	Project Work Phase II	0	0	24	400
<b>TOTAL</b>		<b>0</b>	<b>0</b>	<b>24</b>	<b>400</b>

**LIST OF ELECTIVES**

<b>Subject Code</b>	<b>Subject Name</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
<b>THEORY</b>					
07WTE01	Special Experimental Techniques	3	0	0	100
07WTE02	Welding Procedures for Specific Applications	3	0	0	100
07WTE03	Automation and Application of Robots in Welding	3	0	0	100
07WTE04	Welding Economics and Management	3	0	0	100
07WTE05	Fracture Mechanics	3	0	0	100
07WTE06	Brazing, Soldering, Surfacing and Cutting	3	0	0	100
07WTE07	Welding Codes and Standards	3	0	0	100
07WTE08	Life Assessment of Welded Structure	3	0	0	100
07WTE09	Repair Welding and Reclamation	3	0	0	100
07WTE10	Process Modeling and Application	3	0	0	100
07WTE11	Corrosion and Surface Engineering	3	0	0	100
07WTE12	Total Quality System and Engineering	3	0	0	100

## SEMESTER - I

07WT101 PROBABILITY AND STATISTICS

L T P M  
3 1 0 100

### UNIT - I PROBABILITY AND RANDOM VARIABLES (12)

Probability - Random variables - Moments - Moment generating function - Standard distributions - Functions of random variables - Two-dimensional R. vs. - Correlation and Regression.

### UNIT - II ESTIMATION THEORY (12)

Principle of least squares - Regression - Multiple and partial correlations - Estimation of Parameters - Maximum likelihood estimates - Method of moments.

### UNIT - III TESTING OF HYPOTHESIS (12)

Sampling distributions - Test based on Normal, t-distribution, Chi-square and F-distributions - Analysis of Variance - One way and Two-way classifications.

### UNIT - IV DESIGN OF EXPERIMENTS (12)

Completely Randomized Design - Randomized Block design - Latin square design - 2 Factorial Design.

### UNIT - V TIME SERIES (12)

Characteristics and Representation - Moving Averages - Exponential smoothing - Auto Regressive Processes.

Lecture 45 Tutorial 15 Total 60

### Reference Books

- 1 Freund John, E. and Miller, Irwin, "Probability and Statistics for Engineering ", 5th Edition, Prentice Hall, 1994.
- 2 Jay, L. Devore, "Probability and Statistics for Engineering and Sciences", Brooks/Cole Publishing Company Monterey, California, 1982.
- 3 Montgomery D.C and Johnson, L.A., " Forecasting and Time Series ", McGraw-Hill.
- 4 Anderson, O.D., " Time Series Analysis: Theory and practice ", I. North - Holland, Amsterdam, 1982.
- 5 Gupta, S.C. and Kapur, V.K." Fundamentals of Mathematical Statistics ", Sultan Chand and Sons, New Delhi, 1999.

### WEB REFERENCES:

- 1 [www.maths.adelaide.edu.AU/Applied/Courses/Hps.html](http://www.maths.adelaide.edu.AU/Applied/Courses/Hps.html).
- 2 [www.cs.cf.ac.UK/Dave/A12/nodes86.html](http://www.cs.cf.ac.UK/Dave/A12/nodes86.html).

**UNIT - I CLASSIFICATION OF WELDING PROCESSES- HEAT SOURCES AND WELDING METHODS (12)**

Gas Welding: Gases – setup of equipment – Flame characteristics, different kinds of flame and their areas of application, Weld quality – applications- variants of oxy-gas welding.

Manual Metal Arc Welding: The process, power sources, Function of flux covering, different type of electrodes and their application, electrode designations- defects in welding.

**UNIT - II SUBMERGED ARC WELDING (12)**

The process, power sources, advantages and limitations, process variables and their effects, SAW consumables significance of flux-metal combination, modern developments-applications- defects.

**UNIT - III GAS TUNGSTEN ARC WELDING (12)**

Electrode polarity, shielding gas, use of D.C. suppressors, arc starting and stopping, choice of filler metal composition, use of pulsed arc and GTA spot welding, other recent developments, applications.

**UNIT - IV GAS METAL ARC WELDING (12)**

Considerations of electrodes polarity, shield gas and filler composition. Nature of conditions of spray transfer, difficulties for thin sheet. Dip transfer and CO<sub>2</sub> welding. Flux cored and pulsed MIG welding – other recent developments – applications.

**UNIT - V RESISTANCE WELDING (12)**

Principles of contact resistance, surface preparation, calculation of current, time and voltage for spot welding- Temperature distribution, spot welding cycle, inter-relationship between process variables., Choice of electrode material,. Heat transfer and heat balance. Welding dissimilar combinations. Spot seam, and Projection welding. Upset butt weld, flash butt welding, percussion welding.

**Reference Books****Lecture 45 Tutorial 15 Total 60**

- 1 A.W.S. Welding Handbook. 8th edition. Volume 1 Welding Technology. 1991
- 2 A.W.S. Welding Handbook. 8th edition. Volume 2 Welding Processes. 1991
- 3 Nadkarni. S.V. "Modern Arc Welding Technology". Oxford IBH Publishing Co.1996
- 4 Parmer R.S. "Welding Processes and Technology". Khanna Publishers. 1992
- 5 Lancaster J.F. "The Physics of Welding". Pergamon Press. 1984.
- 6 Houldcraft. P.T., "Submerged Arc Welding". Abington. 1989.
- 7 Metals Handbook (Welding and Brazing) Vol. 6. 10th Edition. ASM 1995.
- 8 A.C. Davies, "Welding"(10th Edition)(1996), Cambridge University Press, ISBN-052156702.

**UNIT - I ELECTRICAL CHARACTERISTICS OF WELDING ARC (10)**

Physical phenomena occurring in the arc potential distribution, static and dynamic arc characteristics. Brief ideas on heat generation, types of forces and metal transfer in the arc. Arc blow power source characteristics. Volt-Ampere relationship and its measurement operating point of the arc, variation of current and voltage with arc length. Arc length control.

**UNIT - II WELDING TRANSFORMERS AND RECTIFIERS (9)**

Basic principles, different methods of control of volt ampere characteristics, Operation - volt control, slope control, dual control use of chokes and saturable Reactors, Resistance welding transformers. Welding rectifiers, choice of diode Material, various types of control of output characteristics, Use of thyristors.

**UNIT - III ROTATING MACHINES (9)**

Alternators and D.C. generators for welding, three brush generator, setting of power source characteristic. DC motors, synchronous motors. Choice of power sources for different welding processes.

**UNIT - IV CONTROLS IN WELDING MACHINES (9)**

Wire-feed system, Carriage movement control, crater filling devices in up and down slopes, seam tracking devices, magnetic control of caroms, pulsing techniques, Sequences control of welding machines, NC and computer –controlled welding Machines, controls in resistance welding machines.

**UNIT - V ELECTRICAL MEASUREMENTS IN WELDING (8)**

Measurement of welding current, voltage temperature, load and displacement, X-Y and strip chart recorders, CRO, LVDT, arc welding analyser, resistance welding monitor.

**Total 45****Reference Books**

- 1 A W S Welding Handbook. Volume 2. 8th edition, 1992.
- 2 Say M.G. "Electrical Engineers Reference Book", 1973.
- 3 Richardson. D.V. "Rotating Electric Machinery and Transformer Technology". Prentice Hall of India, 1978.
- 4 Siemens Aktlengesel Chart. "Electrical Engineering" Hand Book, 1987.
- 5 Jean Cornu, "Advanced Welding Systems", (Vol. 2), Jaico Publishing House, (19940 ISBN 81-7224-267-0.

**UNIT - I PHASE TRANSFORMATION** (9)

Nucleation and crystal growth during solidification – Diffusion laws and kinetics- Important features of pearlitic, bainitic and martensitic transformations – Significance of TTT and CCT diagrams – Recovery recrystallization and grain growth.

**UNIT - II STEELS** (9)

Introduction to specifications – plain carbon steels – low alloy and Q and T steels dual phase steels – Ultra high strength steels – maraging steels – HSLA steels – steels for magnetic and electrical applications, processing, properties & applications.

**UNIT - III STAINLESS STEELS AND CAST IRONS** (9)

Stainless steels – phase diagrams – effects of chromium and nickel – ferritic and Austenitic, martensitic, duplex and precipitation hardened stainless steels. Types of Cast Irons- white iron, malleable iron, S.G. Iron alloy cast irons – physical metallurgy, composition of cast irons, properties and applications. Heat treatments of cast irons.

**UNIT - IV NON-FERROUS ALLOYS** (9)

Brasses, bronzes, Cu-Be alloys, Cu-Ni alloys – High Strength Al Alloys, Ti alloys, Ni alloys and Mg alloys - Physical metallurgy composition, properties and applications.

**UNIT - V SPECIAL MATERIALS** (9)

Composite materials, metallic glasses, Intermetallics, super alloys, Advanced structural ceramics – WC, Tic, TaC, Al<sub>2</sub>O<sub>3</sub>, SiC, Si<sub>3</sub>N<sub>4</sub>, CBN and Diamond-properties, processing and applications. Shape memory alloys, polymeric materials, quasi crystals and nano crystalline materials.

**Reference Books** **Total 45**

- 1 Leslie. W.C. "The Physical Metallurgy of Steels". McGraw Hill. 1983.
- 2 Flinn. R.A. and Trojan. P.K. "Engineering Materials and their Applications". 4th Edition, Jaico, 1999.
- 3 Raghavan. V. "Solid State Phase Transformations". Prentice Hall of India, New Delhi. 1993
- 4 Polmear I.J. "Light Alloys Metallurgy of Light Metals". 3rd edition. Arnold Publishers. 1995.
- 5 Askeland. D.R. "The Science and Engineering of Materials". PWT Kent Publishing Company, Boston, 1989
- 6 Pickering F.B. "Physical Metallurgy and Design of Steels". Applied Science Publishers Limited. London. 1978.
- 7 Raghavan V. "Physical Metallurgy – Principles and Practice". Prentice Hall of India. 1993.
- 8 Brick Gardon Philips. "Structure and Properties of Alloys". McGraw Hill. 1976.
- 9 Metals Hand book. 10th edition. Volume 2. ASM. 1995.

## PRACTICALS

07WT105      ADVANCED METALLOGRAPHY LAB      0   0   3   100

### LIST OF EXPERIMENTS

- 1 Study of Metallurgical microscope
- 2 Specimen preparation for microscopic observation
- 3 Microstructure of plain carbon steels
- 4 Microstructure of cast iron
- 5 Determination of the type and size of the graphite flakes in grey cast iron
- 6 Determination of the type, size, no. of the nodules and amount of nodule formation in S.G. Iron.
- 7 Microstructure of alloy steels and welded joints
- 8 Microstructure of important non-ferrous metals and alloys
- 9 Electrolytic Polishing and etching
- 10 Microstructure of welded specimens
- 11 Determination of the amount of phases
- 12 Grain size determination
- 13 Sulphur and phosphorous printing
- 14 Oxide printing
- 15 Macroetching of steels
- 16 Principles of photomicrography
- 17 Photographic printing techniques

**Total      45**

### Reference Books

- 1 ASM Metals Hand Book, Vol. -9, 10<sup>th</sup> edition 1995.
- 2 ASM International, "Metallography Principles & Practice". ASM 1999
- 3 Vander Hoof. G.F., "Metallography: Principles & Practice". McGraw Hill. 1984.

### EQUIPMENTS AND FACILITIES NEEDED

- 1 Microscope
- 2 Belt grinder
- 3 Disc polisher
- 4 Electro-polishing & Etching unit
- 5 Grain size comparison eye pieces & micrometer eye pieces
- 6 Dark room facilities

## SEMESTER - II

<b>07WT201</b>	<b>MECHANICAL BEHAVIOUR OF MATERIALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
		<b>3</b>	<b>1</b>	<b>0</b>	<b>100</b>

### **UNIT - I DISLOCATION THEORY** (13)

Dislocation – Definition types – Deformation by slip – dislocation movement – slip system – critical resolved shear stress for slip Twinning systems – stacking faults – deformation bands and kink bands – Burger’s circuits – cross slip – dislocation reaction – partial dislocations- sessile dislocation stress fields and energies of dislocation – forces on dislocations – forces between dislocations – dislocation climb – intersection of dislocation-jogs – dislocations sources – multiplication of dislocations – dislocation pile-ups. Effect of temperature, strain and strain rate on plastic behavior, super plasticity.

### **UNIT - II STRENGTHENING MECHANISMS** (12)

Theory of work hardening cold worked structure – grain boundary strengthening- yield point phenomena – strain-aging solid solution strengthening – Precipitation hardening dispersion strengthening- Bauschinger effect – preferred orientation (Texture) fiber strengthening, poly phase strengthening.

### **UNIT - III FRACTURE AND FRACTURE MECHANICS** (12)

Types of fracture in metals – Theoretical cohesive strength of metals – Griffith theory of brittle fracture – Theory of Brittle fracture – theory of ductile fracture – theory of ductile to brittle fracture – significance of transition temperature curves Metallurgical factors affecting transition temperature. Notch effects.

Introduction to fracture mechanics, Strain – energy release rate, stress intensity Factor and fracture toughness. Elementary discussions on linear elastic and Elastic – plastic fracture mechanics and crack opening displacement. Experimental determination of KIC and critical COD and J integral R curve. Toughness of materials

### **UNIT - IV FATIGUE** (11)

Fatigue testing, factors affecting fatigue, structural changes accompanying fatigue, formation of fatigue cracks and fatigue failure. Cumulative damage. Low cyclic fatigue. Application of fracture mechanics to fatigue crack propagation. Effect of temperature on fatigue, statistical analysis of fatigue data.

### **UNIT - V CREEP** (12)

Introduction to creep – creep curve, creep mechanisms, variables affecting creep, presentation and practical application of creep data, accelerated creep testing, and time – temperature parameters for conversion of creep data, development of creep resistant alloys, creep testing- high temperature material problem, stress rupture test, parametric approaches in presenting creep data – Larsen Miller parameter – Manson Hafred parameter.

### **Reference Books** **Lecture 45 Tutorial 15 Total 60**

- 1 Dieter G. E. “Mechanical Metallurgy”, SI metric Edition, McGraw Hill Books. 1988.
- 2 Courtney T. H. “Mechanical Behavior of Materials”, 2<sup>nd</sup> edition, McGraw Hill. 2000.
- 3 Hertzberg. R.W. “Deformation and Fracture Mechanics of Engineering Materials”, John Wiley. 1996.
- 4 Rose. R.M. Shepard L.A. Wulff. J. “Structure and Properties of Materials”, Vol. 3, Mechanical Behavior. 4<sup>th</sup> edition. John Wiley. 1984.
- 5 Smallman R.E. “Modern Physical Metallurgy”, Butterworths, 4<sup>th</sup> edition, 1985.
- 6 Meyers M.A. Chawla. K.K. “Mechanical Behaviour of Materials”, Prentice-Hall International Inc. 1999.

**UNIT - I THERMAL CYCLES IN WELDING (9)**

Heat flow-Basic heat transfer equations, temperature distributions and cooling curves- Influence of heat input, Joint Geometry, plate thickness, preheating and other factors. Comparison of welding processes based on these considerations. Solidification – Epitaxial growth – weld metal solidification – cellular and columnar structures – effect of welding parameters – absorption of gases – gas/metal and slag/metal reactions.

**UNIT - II WELDING METALLURGY OF STEELS (9)**

Effects of steel composition on weldability - formation of different microstructural zones in welded plain carbon steels, C-Mn Steels Phase transformation in weld and heat affected zones – formation of acicular ferrite – carbon equivalent – concept of preheating and post heating – considerations governing their choice and applications. Cold cracking – Factors affecting cold cracking- remedies. Hot cracking of steels- Factors affecting hot cracking-remedies. Weldability – Concept, testing methods.

**UNIT - III WELDABILITY OF STEELS (9)**

Weldability of low alloy steels, Steels for low and high temperature use, all types of stainless steels, Cast Irons and selection. Also selection of welding process and procedure appropriate for each steel.

**UNIT - IV WELDABILITY OF NON-FERROUS ALLOYS (9)**

Weldability of aluminum and its alloys, copper and its alloys, Titanium and its alloys Ni and its alloys and Mg and its alloys – Selection of welding process and procedure appropriate for each material.

**UNIT - V DISSIMILAR WELDING AND WELDING DEFECTS (9)**

**Dissimilar welding:** Metallurgical problems in dissimilar welding- calculation of dilution- methods of controlling dilution - techniques of dissimilar welding- welding of various dissimilar metals combinations like steels, cast irons, Al, Cu, Mg, Ni to other alloys.

**Welding Defects:** Lamellar tearing and reheat cracking. Defects in welded joints: Origin, effects, and remedies. Arc welding defects, resistance welding defects, defects in friction welding, defects in welds of other welding processes.

**Reference Books****Total 45**

- 1 Linnert. G.E. "Welding Metallurgy", Vol. 1 and 2. 4<sup>th</sup> edition. A W S. 1994.
- 2 Granjon. H. "Fundamentals of Welding Metallurgy". Jaico Publishing House. 1994.
- 3 Easterlin. K.E., "Introduction of Physical Metallurgy of Welding", 2<sup>nd</sup> edition. Butterworths Heinmann. 1992.
- 4 Saferian D. "The Metallurgy of Welding". Chapman and Hall. 1985.
- 5 Kou. S. "Welding Metallurgy", John Wiley & Sons. 1987.
- 6 Norman Bailey. "Weldability of Ferritic Steels". Jaico Publishing House. 1997.
- 7 Parmer R.S. "Welding Engineering and Technology", Khanna Publishers. 1997.
- 8 Lancaster J.F. "Metallurgy of Welding", George Allen & Unwin. Boston. 1980.
- 9 AWS Welding Hand book. 8<sup>th</sup> edition. Vol-1. Welding Technology. 1998.

### UNIT - I DESTRUCTIVE TESTING OF WELDMENTS (9)

Tensile tests, impact tests, all-weld - metal tests, COD test, transverse test, Nick-break test, bend tests, hardness tests, hot cracking tests, cold cracking tests, transition temperature test. Experimental stress analysis.

### UNIT - II BASIC CONCEPTS OF NDT (9)

Relative merits and limitations of NDT vs. Conventional testing –Visual inspection, thermal inspection methods.

#### Liquid penetrant Inspection:

Principles, applications advantages and limitations, Dyes, developers, and cleaners, fluorescent penetrant test application of liquid penetrant testing to weldments

#### Magnetic particle Inspection:

Principle application magnetisation methods magnetic particles, dry and wet technique, demagnetisation. Principles application and Instrumentation of Eddy current testing.

### UNIT - III X-RAY RADIOGRAPHY (9)

Types of radiation, properties of X-rays relevant to NDE, absorption of X-rays, scattering, types and use of filters and screens, geometric factors, inverse square

Law, film types and processing, characteristics of films – grain fineness, density, speed contrast characteristic curves, penetrameters, Exposure charts, radiographic equivalence.

#### Gamma ray Radiography:

Gamma ray sources, comparison with X ray radiography radioactive decay, artificial radioactivity, characteristics of Gamma ray sources, Gamma exposure chart. Measurement of radioactivity, radiation hazards, units of radiation dose measurement, permissible radiation dose, radiation detection and measurement instruments, protection against radiation. Brief description of flouroscopy, gamma radiography. standard radiographs, Interpretation of radiographs application of radiographic testing to weldments.

### UNIT - IV ULTRASONICS (9)

Types of ultrasonics waves, principles of wave propagation characteristics of ultrasonic waves, attenuation production of ultrasonic waves couplants. Inspection methods – Pulse echo, transmission and resonance, thickness measurement. Types of scanning., test blocks IIW reference block. Calibration of ultrasonic equipment application of ultrasonic testing to weldments.Holography acoustic emission techniques Miscellaneous techniques like leak testing, pressure testing, chemical spot testing spark testing

### UNIT - V INSPECTION AND QUALITY CONTROL (9)

Principles of inspection, inspection organization, qualification of inspectors, authority and responsibility, quantum of inspection, types of inspection, statistical quality control. Welding procedure specification, procedure qualification records, performance qualification, variables.

#### Reference Books

**Total 45**

- 1 Hull. "Non Destructive Testing". ELBS Edition. 1991.
- 2 Baldevraj., Jayakumar.T., Thavasimuthu. M., "Practical Non-destructive Testing". Narosa Publishers. 1997.
- 3 McGonnagle. W.T. "Non-Destructive Testing", McGraw Hill. 1961.
- 4 Nadkarni. S. V. "Modern Arc Welding Technology", Oxford IBH. 1996.
- 5 Montgomery. C. Douglas. "Introduction to Statistical Quality Control. 2<sup>nd</sup> Edition, John Wiley and Sons. 1991.
- 6 Mohamed Zairi. "Total Quality Management for Engineers", Woodhead Publishing Limited. 1991.
- 7 ASM Metals Hand Book. Vol. 9. "Non-destructive Testing and Inspection", 1988.

**UNIT - I SOLID STATE WELDING PROCESSES (9)**

Fundamental principles, survey of the various pressure welding processes and their applications. Friction, friction stir, explosive, diffusion, and Ultrasonic welding – principles of operation, process characteristics and application.

**UNIT - II ELECTRON AND LASER BEAM WELDING (9)**

Heat generation and regulation, equipment details in typical set-up, electron beam welding in different degrees of vacuum, advantages and disadvantages, applications. Laser Welding: Principles of operation, advantages, and limitations, applications.

**UNIT - III ELECTRO SLAG WELDING (9)**

Heat generation, principles of operations, wire and consumable guide techniques, selection of current, voltage and other process variables, nature of fluxes and their choice. Electro-gas welding: Principle and applications. Narrow gap welding, Under Water welding.

**UNIT - IV PLASMA ARC WELDING (9)**

Special features of plasma arc- transferred and non transferred arc, key hole and puddle-in mode of operation, micro low and high current plasma arc welding and their applications, plasma cutting, surfacing and applications.

**UNIT - V OTHER WELDING PROCESSES (9)**

Adhesive bonding and Welding of plastics, Cold pressure welding, High frequency Welding, Stud welding, Welding automation.

**Total 45****Reference Books**

- 1 Schwartz M.M. "Metals Joining Manual". McGraw Hill Books. 1979.
- 2 Tylecote R.F. "The Solid Phase Welding of Metals". Edward Arnold Publishers Ltd. London. 1968.
- 3 AWS- Welding Hand Book. 8<sup>th</sup> Edition. Vol- 2. "Welding Process", 1998.
- 4 Nadkarni S.V. "Modern Arc Welding Technology", Oxford IBH Publishers. 1996.
- 5 Christopher Davis. "Laser Welding- Practical Guide". Jaico Publishing House. 1994.

## PRACTICALS

<b>07WT205</b>	<b>TECHNICAL SEMINAR</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
	(Internal Evaluation only)	<b>0</b>	<b>0</b>	<b>3</b>	<b>100</b>

Students have to present a minimum of three seminar papers on the topics of current interest. The evaluation will be based on the knowledge of the student on the subject of presentation, their communication abilities, the method of presentation and the way of questions are answered.

**Total 45**

## PRACTICALS

<b>07WT206</b>	<b>WELDING METALLURGY LABORATORY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
		<b>0</b>	<b>0</b>	<b>3</b>	<b>100</b>

### LIST OF EXPERIMENTS

- 1 Arc striking practice – fabrications of simple joints
- 2 Effect of welding parameters on weld bead geometry
- 3 Micro-hardness survey for weldments
- 4 Metallography of ferrous and non-ferrous alloy weldments – Similar and dissimilar joints
- 5 Study on effect of preheating and post weld heat treatments.

**Total 45**

## SEMESTER - III

<b>07WT301 DESIGN OF WELDMENTS AND FAILURE ANALYSIS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
	<b>3</b>	<b>0</b>	<b>0</b>	<b>100</b>

### **UNIT - I DESIGN BASICS** (9)

Type of Joints, joint efficiency, factor of safety, symbols, selection of edge preparation, Design consideration, types of loading.

### **UNIT - II STATIC LOADING** (9)

Permissible stress, allowable defects, computation of stresses in welds, weld size, calculations, code requirement for statically loaded structures.

### **UNIT - III DYNAMIC LOADING** (9)

Design for fluctuating and impact loading – dynamic behaviour of joints – stress concentrations – fatigue analysis – fatigue improvement techniques – permissible stress – Life prediction.

### **UNIT - IV DISTORTION AND RESIDUAL STRESSES** (9)

Welding residual stresses – causes, occurrence, effects and measurements – thermal and mechanical relieving, origin and causes – types of distortion – factors affecting distortion – distortion control methods – prediction – correction, jigs, fixtures and positioners.

### **UNIT - V FAILURE ANALYSIS** (9)

Failure analysis – methodology, approaches, tools and techniques of failure analysis, Modes of failure, failure data retrieval, procedural steps for investigation of a failure for failure analysis. Case studies in welding.

### **Reference Books** **Total 45**

- 1 Bladgett. O. W. "Design of Weldments", James F. Lincoln Arc Welding Foundation. 1991.
- 2 Gray T.G.F. "Rational Welding Design", Butterworths, 1982.
- 3 Gurney T.R. "Fatigue of Welded Structures". Cambridge University Press, 1979.
- 4 Rolfe. T., Barsom. J., "Fracture and Fatigue Control of Structures – Applications of Fracture Mechanics", Prentice Hall, 1977.
- 5 Das A.K. "Metallurgy of Failure Analysis". TMH - 1992.
- 6 Metals Hand Book. "Failure Analysis and Prevention". Vol. 10. ASM 1995.

## PRACTICALS

<b>07WT303 PRACTICAL TRAINING (4 WEEKS)</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
	<b>0</b>	<b>0</b>	<b>0</b>	<b>100</b>

Students have to undergo practical training in welding industries for duration of 4 weeks during the previous vacation and submit a report.

## LIST OF ELECTIVES

<b>07WTE01</b>	<b>SPECIAL EXPERIMENTAL TECHNIQUES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>100</b>

### **UNIT - I METALLOGRAPHIC TECHNIQUES (9)**

Resolution, depth of focus and components of microscope, polarized light, plane contrast, interference, hot stage and quantitative metallographic techniques – in situ techniques, specimen preparation techniques.

### **UNIT - II X-RAY DIFFRACTION TECHNIQUES (9)**

Characteristic spectrum – Bragg's law – Diffraction methods – Laue, rotating crystal and powder methods. Intensity of diffracted beams – structure factor calculations.

### **UNIT - III STEREOGRAPHIC PROJECTION AND RECIPROCAL LATTICE (9)**

Diffractometer – general feature and optics – proportional scintillating and Geiger counters. X-ray diffraction application in determination of crystal structure, lattice parameter and residual stress – quantitative phase estimation.

### **UNIT - IV ELECTRON MICROSCOPY (9)**

Construction and operation of TEM – Diffraction effects and image formation, specimen preparation techniques, elemental analysis by wavelength dispersive and energy dispersive systems – construction and operation of SEM – atomic force microscopy - analysis of fractured surfaces.

### **UNIT - V ADVANCED CHEMICAL AND THERMAL ANALYSIS METHODS (9)**

X-ray fluorescence, spectrometry, Auger spectroscopy, DTA, DSC and TGA. Stress analysis by strain gauging, high temperature strain gauge technique, Photoelasticity and holography.

**Total 45**

### **Reference Books**

- 1 Philips V.A. "Modern Metallographic Techniques and their Applications", Wiley Interscience, 1971.
- 2 Cullity B.D. "Elements of X- ray Diffraction", 4<sup>th</sup> Edition, Addison Wiley, 1978.
- 3 Thomas. G. "Transmission Electron Microscopy of Metals". John Wiley. 1961.
- 4 Smallman R.E. "Modern Physical Metallurgy", 4<sup>th</sup> Edition, Butterworths. 1985.
- 5 Loretto. M.H. "Electron Beam Analysis of Materials", Chapman and Hall, 1984.

**07WTE02 WELDING PROCEDURES FOR SPECIFIC APPLICATIONS**      **L**   **T**   **P**   **M**  
**3**   **0**   **0**   **100**

**UNIT - I   SELECTION OF WELDING PROCESS** (9)

Groove design consideration - factors influencing selection of groove geometry and dimensions of weld joint for various materials and thicknesses using different welding processes.

**Economic Consideration:** Weldment deposition rates for different welding processes- welding cost estimation, standard data for cost estimation, comparative cost study for various welding procedures.

**UNIT - II   DESIGN CONSIDERATIONS** (9)

Accessibility for welding - residual stresses and serviceability of the welded product - modifications in design to suit welding.

**Weld surfacing and Hard facing:** Specific welding techniques used or weld surfacing and hard facing for different applications.

**UNIT - III   WELDING OF OFFSHORE CONSTRUCTIONS** (9)

Requirement of offshore construction - welding problems in underwater welding - various underwater welding techniques.

**Welding of low temperature containment plants:** Materials used for cryogenic applications, problems of welding. Welding processes and procedures used for welding cryogenic materials.

**UNIT - IV   WELDING OF PRESSURE VESSELS** (9)

Materials used for construction of pressure vessels - welding processes and procedures for welding of pressure vessels - requirement of various codes.

**UNIT - V   REPAIRING OF CASTINGS** (9)

Specific problems in repairing of castings of various materials - welding methods used for repairing and reclamation.

**Micro joining techniques:** Various techniques used for joining of electronic circuits and other micro joining applications.

**Total   45**

**Reference Books**

- 1   A.W.S – Welding Handbook 7<sup>th</sup> edition Volume 3, 1991.
- 2   A.W.S. Welding Handbook 7<sup>th</sup> edition Volume 4, 1991.

**UNIT - I AUTOMATION DEVICES FOR WELDED STRUCTURES (9)**

Pre assembly and tacking by welding - distortion by welding and its prevention - tolerances in welded structures and the concept of automated devices - complexity of devices for pre assembly and mechanization/automation in welding.

**UNIT - II MECHANISATION IN WELDING (9)**

Mechanisation of flat / circular joints thin / thick sheets (Resistance weld/arc weld) mechanization of I beams (arc welding) longitudinal circumferential SA welding (roller blocks, column booms, flux supports) circular / spherical welding joints (rotating tables positioners) manufacture of welding longitudinal welded pipes by induction, TIG, plasma and SA welding of spiral welded pipes.

**UNIT - III MECHANISATION OF PIPE WELDING (9)**

Butt welding, TIG orbital welding of thin and thick Members; MIG/MAG orbital welding induction pressure welding, flash butt welding - tube-tube-plate welding. Automation in pipe welding.

**UNIT - IV CONCEPT OF AUTOMATION LINES (9)**

The tolerances and welding procedures and quality, auxillary equipment (fixture, transport, electrical, pneumatic, hydraulic) welding procedures for automation. Automatic lines for welding, automation of track wheels.

**UNIT - V ROBOTICS IN WELDING (9)**

The concept of robotics, the robot design and its applications for welding, programming of welding robot -tolerances of assemblies for robot welding, auxillary devices for robot welding, new generation of welding robots, self alignment by current arc variation, light spot leading system.  
 Practical application of robots in welding, robots for car body's welding, box fabrication, micro electronic welding and soldering- the efficiency of robotics in welding.

**Total 45**

**Reference Books**

- 1 Kozyrev, "Industrial Robots Handbook", Mir Publishers, Moscow.
- 2 "The Procedure Handbook Arc Welding", Lincoln Electric. USA.
- 3 Welding Handbook, Vol. 3, 7<sup>th</sup> edn., A W S.
- 4 Proceedings of the International Conference on Assembly Automation, 1981, British Welding Institute. 1981.

**UNIT - I FACTORS INFLUENCING WELDING COST (9)**

Welding design- selection of electrodes, size, type and metal recovery – electrode efficiency, sub, thrown away electrodes – over welding and joint fit – up welding position - operation factor – jigs, fixtures, positioners, Operator efficiency.

**UNIT - II ESTIMATION OF WELDING TIME (9)**

Need for time standard – definition of standard time- various methods of computing standard time – analytical calculation – computerisation of time standards.

**UNIT - III COSTING FOR WELDING (9)**

Definition of terms – composition of welding costs, cost of consumables – labour cost – cost over heads - formulae for total cost – cost curves for different processes like GMAW, SAW, ESW, Mechanisation in welding – job shop operation.

**UNIT - IV PLANT LAY OUT (9)**

Process Vs product lay out – construction – service consideration – employees-services, welding shop equipment, oxy acetylene stations- resistance welding stations – inert gas welding stations – arc welding stations – crane forges - jigs and fixtures; power tools - blast cleaning supplies- welding equipment repair shop - proper arrangement of the above in the welding shop for maximum convenience and ease of production.

**UNIT - V SAFE PRACTICES IN WELDING (9)**

Selection and installation of equipments, safe handling equipment - fire prevention-eye and face protection - respiratory protection - ventilation -protective extra clothing -electric shock- safety analysis.

Planning for welding operations, production control planning for welding processes- pre-production planning- routing - scheduling.

Activating, monitoring, materials management in welding-Inventory control- Basic aspects of financial management and man-power planning.

**Total 45****Reference Books**

- 1 Standard Data for Arc Welding – Welding Institute U.K..1994
- 2 Bathy. J., “Industrial Administration and Management” 1984
- 3 Pendar. J.A., “Welding Projects – A Design Approach”. 1977

**UNIT - I TYPES OF FRACTURE (9)**

Ductile and brittle fracture, features of fracture surface for ductile, brittle and mixed modes, fractography

**Transition temperature approach:** Notched bar impact tests. Ductile to brittle transition, influence of temperature, strain rate and multi-axial loading, limitations of charpy testing. Drop-weight test and other large scale tests – fracture analysis diagram.

**UNIT - II FRACTURE MECHANICS APPROACH (9)**

Stress distributions around discontinuities, stress analysis in simple cracked bodies, plane strain and plane stress conditions, stress intensity factor and fracture toughness.

**UNIT - III YIELDING FRACTURE MECHANICS (9)**

Concept of crack opening displacement, calculation of COD. The J contour integral-derivation of J from load – displacement diagram. The relationship between J and COD

**UNIT - IV EXPERIMENTAL MEASUREMENT OF FRACTURE TOUGHNESS (9)**

$K_{IC}$  testing – test piece requirements and types, fatigue pre-cracking, determination of COD, estimation of critical COD from the test data. Measurement of J integral and R curve.

**UNIT - V APPLICATIONS OF FRACTURE MECHANICS (9)**

Concepts of tolerable defects, use of fracture mechanics in design and material selection.

**Total 45****Reference Books**

- 1 David Broek, "Elementary Engineering Fracture Mechanics", Sijthoff Noordhoff, 1978.
- 2 Tetelmen A.S. and McEvily. A.J. "Fracture of Structural Materials". John Wiley & Sons, 1967.
- 3 Hertzberg R.W. "Deformation and Fracture Mechanics of Engineering Materials" 3<sup>rd</sup> edition, John Wiley 1989.



**UNIT - I WELDING PROCEDURE AND WELDER QUALIFICATION (9)**

Welder procedure specification, procedure qualification records performance qualification,

**UNIT - II MATERIALS AND CONSUMABLES (9)**

Introduction to materials standards and testing of materials, consumables testing and qualification as per ASME/AWS requirements

**UNIT - III STRUCTURAL WELDING CODES (9)**

Design requirements, allowable stress values, workmanship and inspection

**UNIT - IV PETROLEUM PIPING FABRICATION (9)**

Process and product standards for manufacturing of pipe – welding procedure and welder qualifications, field welding and inspection.

**UNIT - V PRESSURE VESSEL FABRICATION (9)**

Design requirements fabrication methods, joint categories, welding and inspection, post weld heat treatment and hydrotesting.

**Total 45****Reference Books**

- 1 AWS D1.1 Structural Welding Code
- 2 API 5L
- 3 API 1104
- 4 ASME Section VIII – Division 1
- 5 ASME Section IX
- 6 ASME Section II Part A and C
- 7 Howard B.Cary “Modern Welding Technology” –Prentice Hall International Inc; London -1979-ISBN 0-13-5992 90 -7.

<b>07WTE08</b>	<b>LIFE ASSESSMENT OF WELDED STRUCTURES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>100</b>

**UNIT - I NEED FOR REMAINING LIFE ASSESSMENT (RLA) IN PLANTS (6)**

Historical evolution and operation of power plants and petrochemical plants – general description, temperature, pressures and materials, failure in plants, definition of zero failure.

**UNIT - II MATERIAL PROPERTIES CONSIDERED FOR RLA (6)**

Toughness, DBTT, LEFM, EPFM, temper embrittlement, hydrogen embrittlement.

**UNIT - III CREEP (9)**

Mechanisms, parametric extrapolation techniques – LM, OSD, MII, MB and MCM, design rules, cumulative damage, crack growth models, RLA methodology for bulk and localized damages.

**UNIT - IV FATIGUE (12)**

High and low cycle fatigue, Coffin-Manson relationship, creep fatigue interaction, effect of hold time, frequency strain concentration, environment, rupture ductility, damage rules and life prediction, design rules for creep fatigue (CF), linear damage summation, failure mechanism maps, thermal fatigue (TF), thermal-mechanical fatigue (TMF), thermal fatigue (TF), thermal-mechanical fatigue (TMF), thermal-mechanical fatigue life prediction, crack growth in fatigue.

**UNIT - V LIFE PREDICTION FOR POWER PLANT COMPONENTS (12)**

Materials, damage mechanisms and RLA of boiler tubes, header, steam pipes, roots, steam casings, valves and steam chests, steam turbines blades, high temperature bolts, Non-destructive assessment methods for extent of creep damage, replication, creep pipes, principles of micro-thermography, effective temperature determination by implanting diffusion couples, life prediction of petroleum pressure vessel-materials for hydrogen service, materials of construction, integrity consideration of pressure vessel shells and cladding RLA techniques for improved alloys, Arkhausen Noise.

**Total 45**

**Reference Books**

- 1 Karl Hauffe, "Oxidation of Metals", Plenum Press, 1981.
- 2 Viswanathan R. "Life Assessment and Improvement of Turbo-generators Rotors for Fossil Plants", Pergamon Press, 1985.
- 3 Viswanathan. R, "Damage Mechanisms and Life Assessment of High Temperature Components", American Society for Metals, 1989.
- 4 Das. A. K. "Metallurgy of Failure Analysis", Tata McGraw Hill, 1993.

**UNIT - I REPAIR WELDING (10)**

Engineering aspects of repair, aspects to be considered for repair welding, techno-economics, repair welding procedures for components made of steel casting and cast iron, full-mould process, AWA bath tub test for cast iron repair, special procedures to avoid post-repair stress relief heat treatment, half bead, temper bead techniques, usage of Ni based filler metals.

**UNIT - II REPAIR TECHNIQUES FOLLOWED IN SPECIFIC APPLICATIONS (10)**

Damaged bends in gas transmission pipe lines, heat exchanger repair techniques – explosive expansion, plugging, creep damaged high temperature components, repair of cracked petroleum pressure vessel/ reactor.

**UNIT - III RECLAMATION (6)**

Types of wear, wear resistant materials, selection of materials for various wear applications, reclamation surfacing techniques. Selection of welding processes for reclamation.

**UNIT - IV MAINTENANCE WELDING IN NUCLEAR POWER PLANTS (9)**

Integrating repair/maintenance into on-going operation, radiation protection, steam generators repair, plugging.

**UNIT - V EVALUATION OF SURFACE COATINGS (10)**

Various types of hardness tests, NDE of surface coatings, characterization of coatings, photo-thermal imaging, case studies on selection, application and materials combination.

**Total 45****Reference Books**

- 1 “Recommended Practice for Repair Welding and Fabrication Welding of Steel Casting”, Steel Foundry Research Foundation, 1981.
- 2 Lim Cottrel C., “Welding Cast Irons”, The Welding Institute, 1991
- 3 “Weld Surfacing and Hardfacing”, The Welding Institute, 1987.
- 4 Nagendra Reddy A., “Maintenance Welding Made Easy”, Jaico Publishing House, 1997.

<b>07WTE10</b>	<b>PROCESS MODELING AND APPLICATIONS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>M</b>
		<b>3</b>	<b>0</b>	<b>0</b>	<b>100</b>

**UNIT - I INTRODUCTION TO MODELING AND PROCESS CONTROL (9)**

Mathematical modeling, physical simulation – advantages and limitations, process control and instrumentation – use of converters, gauges, thermocouples and other sensors.

**UNIT - II MATHEMATICAL CONCEPTS (9)**

Review of differential equations and numerical methods – introduction to FEM, FDM, CFD and heat transfer analysis.

**UNIT - III SOFTWARE PACKAGES AND EXPERT SYSTEMS (12)**

Introduction to standard software packages like ANSYS, IDEAS, DEFORM. Introduction to expert systems, applications of expert systems in metallurgical processes, use of artificial intelligence, practical training in some software packages.

**UNIT - IV COMPUTER APPLICATIONS IN PHYSICAL METALLURGY (6)**

Use of computer for the construction of phase diagrams, alloy design and crystallography.

**UNIT - V COMPUTER APPLICATIONS IN PROCESS METALLURGY (9)**

Modeling of solidification, heat transfer, fluid flow, casting, welding and liquid metal treatment.

**Total 45**

**Reference Books**

- 1 Piwonka T.S., Vollen V., Katgerman L., "Modeling of Castings, Welding and Advanced Solidification Processes", 4<sup>th</sup> edition. TMS-AMIE., 1993.
- 2 Stocks G.M., Turchi P.E.A., "Alloy Modeling and Design", The Metals Society – AMIE, 1994.
- 3 Trivedi R., Sekhar J.A., Majumdar J., "Principles of Solidification and Materials Processing", Vol. 1 and 2., Oxford and IBH, 1989.
- 4 Cerjak H., 'Mathematical Modeling of Weld Phenomena'. – 2, The Institute of Materials, 1995.

**UNIT - I MECHANISMS AND TYPES OF CORROSION (9)**

Principles of direct and Electro chemical Corrosion, Hydrogen evolution and Oxygen absorption mechanisms – Galvanic corrosion, Galvanic series-specific types of corrosion such as uniform, Pitting, Intergranular, Cavitations, Crevice Fretting, Erosion and Stress Corrosion –Factors influencing corrosion

**UNIT - II TESTING AND PREVENTION OF CORROSION (9)**

Corrosion testing techniques and procedures- Prevention of Corrosion-Design against corrosion –Modifications of corrosive environment –Inhibitors – Cathodic Protection –Protective surface coatings.

**UNIT - III CORROSION BEHAVIOR OF MATERIALS (9)**

Corrosion of steels, stainless steel, Aluminum alloys, copper alloys, Nickel and Titanium alloys- corrosion of Polymers, Ceramics and Composite materials.

**UNIT - IV SURFACE ENGINEERING FOR WEAR & CORROSION RESISTANCE (9)**

Diffusion coatings –Electro and Electroless Plating –Hot dip coating –Hard facing- Metal spraying, Flame and Arc processes- Conversion coating –Selection of coating for wear and Corrosion resistance.

**UNIT - V THIN LAYER ENGINEERING PROCESSES (9)**

Laser and Electron Beam hardening –Effect of process variables such as power and scan speed - Physical vapor deposition, Thermal evaporation, Arc vaporization, Sputtering, Ion plating - Chemical vapor deposition – Coating of tools, TiC, TiN, Al<sub>2</sub>O<sub>3</sub> and Diamond coating – Properties and applications of thin coatings.

**Total 45****Reference Books**

- 1 Fontana. G., "Corrosion Engineering", McGraw Hill, 1985.
- 2 Serope Kalpakjian – "Manufacturing Engineering & Technology- Addison Wesley Publishing Co; New York 1995.
- 3 Schweitzer. P.A., "Corrosion Engineering Hand Book", 3<sup>rd</sup> Edition, Marcel Decker, 1996.
- 4 Winston Revie.R. Uhlig, Corrosion, Hand Book 2<sup>nd</sup> edition. John Wiley, 2000.
- 5 Kenneth G.Budinski, "Surface Engineering for Wear Resistance", Prentice hall, 1988.
- 6 ASM Metals Hand Book –Vol. 5, Surface Engineering, 1996.

**Web Reference**

- 1 [www.hw.ac.uk/mecwww/research/an/coserg-2.htm](http://www.hw.ac.uk/mecwww/research/an/coserg-2.htm)

**UNIT - I INTRODUCTION (9)**

Principles of Quality Management – Pioneers of TQM –Quality Cost-Quality System-Customer Orientation –Bench marking – Re-engineering - Concurrent Engineering.

**UNIT - II PRACTICE OF TQM (9)**

Leadership – Organizational Structure- Team Building- Information Systems and Documentation –Quality Auditing-ISO 9000-QS 9000.

**UNIT - III TECHNIQUES OF TQM (9)**

Single vendor Concept –J.I.T –Quality Function Deployment- Quality Circles – KAIZEN- POKA YOKE - Taguchi Methods.

**UNIT - IV STATISTICAL QUALITY CONTROL (9)**

Methods and Philosophy of statistical process control –Control Charts for Variables and Attributes –Cumulative sum and Exponential - weighted moving average control charts- other SPC techniques –Process Capability Analysis –Six Sigma accuracy.

**UNIT - V ACCEPTANCE SAMPLING (9)**

Acceptance sampling Problem –Single Sampling Plans for Attributes –Double, Multiple and sequential sampling, Military standards – The Dodge – Romig Sampling plans.

**Total 45**

**Reference Books**

- 1 Mohamed Zairi, "Total Quality Management for Engineers", Woodhead Publishing limited 1991.
- 2 Harvind Noori and Russel, "Production and operations Management-Total quality and Responsiveness", McGraw-Hill Inc.1995.
- 3 Suresh Dalela and saurabh. "ISO 9000 A manual for Total Quality Management", S.Chand and Company Ltd., 1997.
- 4 John Bank, "The Essence of Total Quality Management", Prentice Hall of India Pvt., Ltd., 1995.
- 5 Monttgomery. D.C. "Introduction to Statistical Quality Control", 2<sup>nd</sup> Edition, John Wiley and Sons, 1991.
- 6 Leavensworth. G.E.L., "Statistical Quality Control", McGraw-Hill,1984.

**WEB REFERENCES**

- 1 [www.ahepr.gov/research/feb00/02000RA15.htm](http://www.ahepr.gov/research/feb00/02000RA15.htm)
- 2 [www.mcb.co.uk/tam.htm](http://www.mcb.co.uk/tam.htm)