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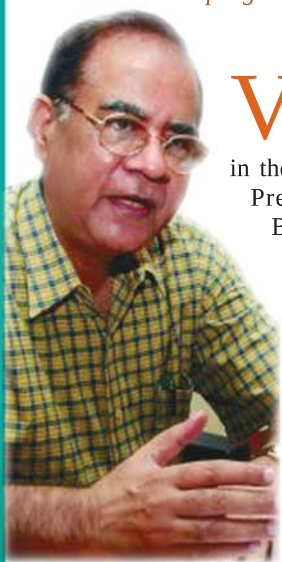
From the Director's Desk

Engineering Research & Development

- Backbone of robust FBR Design

"There is a need for constant interplay between basic sciences, technology and industrial practice if economic progress is to result from the activity undertaken"

Vikram Sarabhai



Vision of the three stage Nuclear Power programme enunciated by Dr. Bhabha, laid the foundation for nuclear power development in the country. The first stage comprises setting up of Pressurised Heavy Water Reactors(PHWR). Fast Breeder Reactors (FBR) which form the second stage, use plutonium based fuels surrounded by depleted uranium blanket to produce more plutonium and enhance nuclear capacity and produce further plutonium. The third stage would comprise uranium233 based thermal reactors to produce power and also efficiently convert thorium232 to uranium233. The third stage will utilise the vast reserves of thorium available in the country, towards meeting large energy demands essential for high pace economic growth trajectory of India.

Fast Breeder Test Reactor (FBTR) heralded India's entry to the second stage of the nuclear power programme. FBTR the flagship of the Indira Gandhi Centre for Atomic Research (IGC Newsletter Vol. 61, July 2004) is not only a test reactor for development of advanced fuels and structural materials, but also a power demonstration reactor. (IGCAR Newsletter Vol: 62, October 2004). It is a synergy of many disciplines that has resulted in the success of FBTR and enabled launching of 500MWe Prototype Fast Breeder Reactor (PFBR) in 2003 (IGC News Letter Vol.69, July 2006). In this article, I will be discussing some aspects of Fast Reactor Technology Development, not

INSIDE

500 kW Sodium Facility

covered in the earlier essays on Fast Reactor Science and Technology, which have appeared in IGC newsletter.

BIRTH OF REL

Towards engineering development for sodium cooled Fast Reactors, the design of a 500 kW sodium facility was initiated in 1968. S/Shri M.C. Sabherwal and A. Venkateswarlu, engineers trained in sodium technology abroad were associated with the design. The construction of this facility was undertaken at Kalpakkam under the guidance of Shri.A.Venkateswarlu initially, and later Shri R.D.Kale, who played the prime role in setting up the Reactor Engineering Laboratory (REL). The facility was setup with an electrical heat source, a sodium to sodium heat exchanger, a mechanical sodium pump and a sodium to air cooler. The design, construction and operation of this facility has given a good insight into heat transfer aspects, detection and handling of sodium leaks besides training manpower for FBTR operation. A sodium purification loop was also set up to treat three tons of commercial grade sodium from indigenous supplier for use in the facility. Sodium of reactor grade was obtained by removing impurities by means of circulating sodium through a cold trap. Shri.R. Subramanian supported by Shri.M.Rajan was responsible for this activity, which provided the base for setting up a large scale purification facility for FBTR.

SUPPORT TO FBTR

Right from its inception the focus of REL, was towards providing inputs for successful commissioning and operation of FBTR. The working team comprised young enthusiastic engineers from the training school viz. S/Shri. K. Swaminathan, Late R. Selvaraj, R.Prabhakar, M. Rajan, K. Balachander, K.K. Rajan and a good number of scientific assistants and tradesmen, all trying their hands on a new technology. Development of Rupture Disc for use as safety device against over pressure in the FBTR Steam Generator was a challenge. A task force under the leadership of Shri. S.C. Chetal took up the challenge and finally a rupture disc with 5 milli seconds response time was developed, tested in house and used in FBTR. This is an example of technology denied serving as a motivator for developing technology. Development of flat linear induction pump, electromagnetic flowmeters, eddy current flowmeter and sensitive sodium ionization type leak detectors etc. were relentlessly pursued by the team. Mastering of purification technology in the earlier years, led to successful purification of 150 tonne of commercial grade sodium into reactor grade and its transportation to FBTR in batches.

Development of Rupture Disc for use as safety device against over pressure in the FBTR Steam Generator was a challenge.

THERMAL HYDRAULIC ANALYSIS

Towards thermal hydraulic analysis for FBTR, the Reactor Operation Studies team, under the leadership of Shri.G. Vaidyanathan developed the indigenous computer codes for steady state operation, plant dynamics from reactor to steam water system and process design of once through steam Generators used in FBR's. The programmes were written in such a modular fashion, that in the 80s, the same codes with minor modifications for Pool type reactor assembly could be used for Prototype Fast Breeder Reactor. Later, during tests done at FBTR, it was noted that the measured data matched closely with the predictions. Having gained confidence in developing 1D codes, the team embarked upon development of 2D and 3D computer codes.

The thermal hydraulic analysis of FBTR with the core cover plate mechanism stuck in a higher position than normal, was carried out with 2D and 3D computer codes. The results matched closely with measured data and gave confidence to the regulatory authorities to clear operation under changed conditions.

The analysis expertise developed at IGCAR has also benefited the PHWR programme. One example is the evaluation of the flow and temperature patterns in the moderator system of MAPS reactor at Kalpakkam, after the manifold failure. Based on the findings

MAPS was restarted and went upto maximum of 50% power, as a part of short term rehabilitation works carried out under the able and enthusiastic leadership of Dr. Anil Kakodkar, the then Associate Director(Reactor Group), BARC and present Chairman,AEC. Later , the power was raised in steps and full power reached after addition of spargers in the moderator system.

PFBR R&D APPROACH

It was abundantly clear, that the realization of PFBR necessitated a lot of engineering rigs and large scale experiments in water and sodium. Experiments in sodium are complex, time consuming and costly. So the approach has been to carry out experiments with similitude coolants like water and air for the hydraulics aspects. The judicious mix of analysis and experimental approach, has provided insight into the processes governing the mechanical and thermal loading. It would not be out of place to say that the marriage of advanced computations with experiments has created a comprehensive capability in solving many thermal hydraulic problems at this Centre.

SODIUM PUMP

The development of large circulating sodium pumps of centrifugal type for PFBR was a challenging task,taken up in collaboration with industry, under the leadership of Shri.R.D.Kale. The first phase in this programme dealt with the development of the sub-assemblies of the pump such as hydraulic model study, manufacture of special stainless steel castings, pump shaft and so on. The second phase consisted of building a full scale prototype and its performance tests. Meanwhile, a parallel effort made at IGCAR towards gaining insight into pump design and construction experience, resulted in the indigenous construction of a small capacity pump (50 m^3/h). Cavitation performance of the pump was studied and the pump was also subjected to a short-term endurance test in 500 kW sodium facility. Fabrication of long stainless steel shaft (7.2m) for the PFBR pump was an engineering marvel, consisting of a central hollow portion welded to two solid sections at ends, needing accurate finish machining. Visual cavitation tests were performed on the model pump fitted with transparent (Perspex) suction casing. Greater challenge was faced, when the overall size had to be reduced from economic considerations. A new scale model was fabricated and paint erosion test deviced to verify absence of cavitation. This work was executed successfully, with IGCAR and the industrial partner M/s Kirloskar Brothers acting as a team from design to completion of testing.

INTERMEDIATE HEAT EXCHANGER

The Intermediate Heat Exchanger (IHX) is another important component requiring robust design and validation. Studies, in the 500 kW facility had given insight into the heat transfer process . As a prelude to the testing of IHX for Flow Induced Vibration (FIV), measurements were carried out on a three tube model. Natural frequency and mode shapes were determined and these matched well with theoretical predictions. Flow induced vibration test of IHX sector model in water, with instrumented tubes, fixed with strain gauges and accelerometers, qualified the design.

POOL THERMAL HYDRAULICS

In a pool type reactor of PFBR type, complex flow and temperature patterns exist under different operating conditions. In this direction, thermal hydraulic studies have been completed in three scale models to cover the range of similitude parameters. Thermal stratification studies simulating hot pool conditions after a reactor scram were conducted. Further a large 1/4 **s**c**a**le **m**odel of **r**eactor **a**ssembly **t**hermal hydraulics(SAMRAT), with large sized components, has been built and a variety of experiments on velocity and flow distribution, thermal stratification, free level fluctuations and gas entrainment have been conducted. Experiments conducted with circumferential baffles on inner vessel have shown their effectiveness in decreasing gas entrainment at free level.The data obtained have been

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Charging of Sodium in Purification loop

1/4 Scale Model of Reactor Assembly of PFBR

With a view to reduce conservatism in design for future FBR steam generators and arrive at an economic design, a 5.5 MWt steam generator test facility has been set up.

very important in qualifying the layout of the hot pool design of PFBR.

CORE SUBASSEMBLY HYDRAULICS

A water rig to test full scale subassemblies of fuel, blanket, reflector etc. besides testing of orifices and labyrinths has been set up. It has helped in the pressure drop and cavitation testing of multihole and honey comb orifices for fuel subassemblies and labyrinths for the grid plate- assembly foot gaps. Flow induced vibration measurements on a 19 pin bundle model of the PFBR fuel subassembly and other measurements have validated the numerical model used.

MAIN VESSEL BAFFLE VIBRATION

As part of experimental flow induced vibration studies on main vessel cooling baffles, natural frequency and damping measurements were completed on baffles made of aluminum and stainless steel in scale models. The study was prompted by the observation of main vessel cooling baffle vibration in Super Phenix reactor in France. The experiment have given a good insight to the process and qualified the design.

GRID PLATE HYDRAULICS

Hydraulic experiments on scale model of PFBR grid plate, in air, were completed in collaboration with Fluid Control Research Institute, Palakkad, Kerala. The objectives of the experiments were to study the flow and pressure distribution at different operating conditions and to select an optimum baffle plate configuration. The setup also gave confidence to the fact that core would not starve of adequate flow during rupture of one of the inlet pipes.

SODIUM EXPERIMENTS

Long duration experiments (4000h) have been conducted to determine sodium mist transfer through the vertical annuli present in the bellowless Control and Safety Rod Drive Mechanism (CSRDM), a concept studied for PFBR. This concept has the advantage, accruing from the elimination of the stainless steel bellows which are known to have limited life. The studies have confirmed the use of bellowless concept. Circumferential temperature asymmetry and sodium aerosol deposition in vertical annuli of top shields have been experimentally studied in a small mockup and in a large diameter test vessel in Large Component Test Rig (LCTR). These tests have validated our predictions and provided us with a physical understanding of the effect of different convection barriers and operation parameters.

STEAM GENERATOR EXPERIMENTS

Steam Generator(SG) is an important component deciding the plant availability and is referred to as Achilles heel of FBR. Many important studies were therefore directed towards this component. Experimental study was carried out in water, on the scale model of the inlet plenum of PFBR steam generator to ensure uniform flow at the entry of tube bundle using different devices. A 60deg. sector model of PFBR steam generator was tested in water for velocity measurements in the inlet plenum and flow induced vibration of tubes. The tests have confirmed our predictions. An experimental rig was commissioned for studying detection of simulated steam generator leaks by acoustic technique. Steam leak signal data received from IAEA for developing noise analysis technique to detect and localize the leak source were analyzed using in-house developed methods. During the 8 MW(t) power operation of FBTR, acoustic noise measurements were carried out on one steam generator module with argon injection and the response of the acoustic transducers was measured. This technique is being improved further to detect onset of water leak in SG.

The Mass Transfer loop has been used to study carbon transfer from the ferritic steel used in SG to the austenitic stainless steel in rest of the secondary sodium system. The BIM loop has been successfully used to study the bimetallic weld between 2.25Cr-1Mo and Stainless steel 316. The SOWART rig has been used for micro water leak studies in SG and is being used to get further data on material wastage due to larger leaks. The rig has also been useful to evaluate different Hydrogen sensors in sodium and argon cover gas. These are essential to detect onset of a sodium water reaction in SG.

With a view to reduce conservatism in design for future FBR steam generators and arrive at an economic design, a 5.5 MWt steam generator test facility has been set up. This simulates the operating parameters of PFBR. Temperature measurements across the height of the tubes in different rows and at steam outlet of tubes give a measure of the performance and give data to tune the predictive tools.

UNDER SODIUM VIEWING

Sodium is opaque to light. However, ultrasonic technique enables us to see through liquid sodium and identify or detect objects kept under sodium. Ultrasonic method was utilized for viewing under sodium in FBTR reactor vessel. The device is particularly useful in scanning the under-space below the core cover plate to detect any projecting subassembly, the complete operation being controlled through a microcomputer. The ultrasonic viewer also gave an indication of the maximum displacement of the bent guide tube, after the fuel handling incident in FBTR. Ultrasonic transducers suitable for immersion in liquid sodium up to a temperature of 473K (200°C) have been developed.

MAGNETIC SENSORS

Electromagnetic flowmeters have been developed and more than 36 flow meters in 12mm to 100mm pipe sizes have been successfully manufactured and tested to achieve robustness of the components. Eddy current flow meters, to measure sodium flow through fuel sub-assemblies, have been successfully developed and perfected after testing in FBTR.

Development of Curie point magnetic switch was started with a multi-disciplinary task force and has resulted in deciding, the correct material composition of the switch after extensive investigations and iterative experiments.

SODIUM SPECIFIC INSTRUMENTS

Sodium level measurement in different capacities are measured continuously by sensors working on the principle of mutual inductance. This technology has been successfully transferred to Industry.

Sodium leak detectors are required to detect even a minute amount of sodium leak, for the safe operation of the rigs and the reactors. Wire type , spark plug type and mutual inductance type detectors have been developed and tested. Sodium ionization detectors (SID) for detecting minute amount of sodium leak, from the pipelines and vessels of the sodium rigs have been developed. These can detect, as low a quantity as a nano gram of sodium in a cubic cm of the carrier gas. The testing of the sensors have been conducted in the SILVERINA loop. It can be said that the SID developed is comparable to International Benchmarks.

SODIUM REMOVAL

The components in sodium systems need to be cleaned free of sodium before attempting their repair, reuse or dismantling. Various cleaning techniques have been developed for different components. Alcohol dissolution has been employed for small and delicate components like valves, bellows etc. Large components such as sodium pump, heat exchangers etc. are cleaned by water vapour-CO_2 in inert gas atmosphere.

SODIUM FACILITIES

Over the years, the Fast Reactor Technology Group at the centre has acquired considerable experience in the design, construction and operation of sodium facilities, decontamination of sodium components, disposal of sodium waste and sodium fire fighting. Starting with the 500 kW facility, the rigs built and operated are the Mass Transfer loop, Bimetallic Loop, SILVERINA loop, Sodium Water

Over the years, the Fast Reactor Technology Group has acquired considerable experience in the design, construction and operation of sodium facilities, decontamination of sodium components, disposal of sodium waste and sodium fire fighting.

Large Component Test Rig

Steam Generator Test Facility

Sodium Fire Fighting

Reaction Test Rig(SOWART), Large Component Test Rig (LCTR) and Steam Generator Test Facility (SGTF).Testing Control & Safety & Diverse safety rod mechanisms, Fuel Handling machines viz. Transfer Arm & Inclined Fuel Transfer Machine (Full Size), and heat & mass transfer studies in cover gas are being conducted in LCTR. A 2 MWt Sodium to Air Exchanger, geometrically similar to that in PFBR, has been successfully tested for heat transfer performance, in SGTF. Also an eddy current inspection tool developed for ISI in SG by the Inspection Technology Group has been tested satisfactorily in SGTF, confirming its utility for PFBR. This facility will also serve as a training ground for PFBR steam Water System operation. The operation experience gained so far from all the sodium rigs has provided valuable inputs for PFBR design and operation. It can be said with high confidence that, we have a team of engineers who are able to design, build and operate sodium systems with a high level of confidence and maturity.

SAFETY

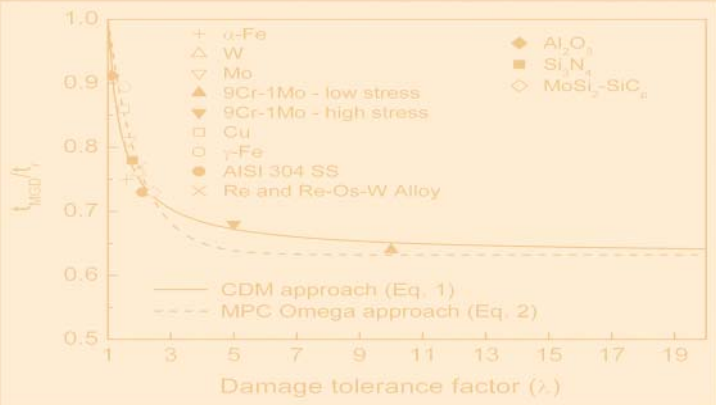
In the event of unlikely sodium fire, the same is extinguished with fire extinguishers containing Dry chemical powder (DCP).To take care of large leaks from components and piping, leak-collection-trays comprising corrugated shape cover with precise entry holes, working on the principle of self extinction by oxygen starvation have been developed and tested.

IN PERSPECTIVE

The growth of engineering development can be gauged from the fact that starting as a Development Section in 1969 with few engineers, today it has become Fast Reactor Technology Group with 300 personnel, its work encompassing all important engineering facets of sodium technology. Human Resource Development has been an important hallmark of this group. It has provided leaders to the other programmes of IGCAR. Shri. K. Balachander after two decades experience, became Head, Central Workshop and later the Regional Director of Directorate of Purchase & Stores at Chennai. Shri.R. Prabhakar after a stint of three decades in the group is presently Director (Technical) in BHAVINI. Shri. N.Vijayan Varier who provided the mechanical design & construction support for sodium rigs for 25 years is presently the centre's Quality Assurance wing leader at Mumbai. Shri. A.S.L.K. Rao who was responsible for Sodium Pump design, after a stint of 28 years in the group, is now Head of Central workshop. Last but not the least Shri.M. Rajan after 32 years stint in sodium technology is now the Director, Safety Group at the centre. The group has also been responsive to accept personnel from other groups. Shri.P. Kalyanasundaram after a 30 year experience in Non Destructive Testing is now a part of this group, bringing in his rich experience in condition monitoring, noise analysis and digital signal processing. These changes have led to good crossbreeding of technical ideas and approaches. This has really benefited the group and department.

Engineering development for Sodium cooled Fast Breeder Reactors has come a long way from its inception in 1970s. Comprehensive expertise has been built up for design and testing of a large number of components. Sodium Handling has become a common affair. Many sensors and related electronics for sodium have been made, tested and technology transferred to industry. The future direction would lie in experiments on large scale models of components with better measurement techniques, which could eventually lead to reduce conservatism in the design. Use of acoustic techniques, improvement in ultrasonic under sodium detection, improved hydrogen meters, development of Integral cold trap for Pool type reactors would also be pursued. The engineering development and testing capability has made a strong base and with this base, achievement of our enhanced goals on Fast Reactors will be a reality.

(Baldev Raj)



A Critical Damage Criterion for Creeping Solids

The slow and progressive deformation of a material subjected to either constant load or stress is termed as creep and is an important fundamental phenomenon; - creeping of ice causes the movement of glaciers, tungsten filament in lamps fail by sagging due to creep and engineering components in energy conversion systems fail due to creep damage. Though it can occur at all temperatures, creep is of major concern at temperatures greater than 0.4 times the melting point on the Kelvin scale. A typical strain–time creep curve mainly consists of a decelerating primary, the so called steady–state or the minimum creep rate secondary creep regime followed by an accelerating tertiary creep eventually resulting in failure of the material. Creeping solids fail as a result of initiation and growth of damage. Creep damage is the progressive reduction in the material's ability to resist stress and is manifested as an increase in deformation rate during tertiary stage leading to failure. It is desirable that the material spends most of its useful time in the secondary creep stage. The product of minimum creep rate $\dot{\varepsilon}_m$ and rupture life t_r i.e., $\dot{\varepsilon}_m.t_r$ (generally found to be constant as proposed by Monkman and Grant five decades ago) is the total secondary strain contribution of creep ductility and is referred to as 'Monkman–Grant Ductility' (MGD). The engineering creep oriented design criterion in arriving at the allowable stresses for nuclear applications is essentially based on the concept of deducing the lowest of the three; i.e., 100% of the average stress to produce 1% strain in a given time (say 10^5 h), 67% of the minimum stress to produce rupture in 10^5 h and 80% of the minimum stress to cause initiation of tertiary creep in 10^5 h. The 1% strain criterion in 10^5 h, in essence, is equivalent to the minimum creep rate of 10^{-7} h^{-1} and this criterion safeguards the material against distortion. Whereas, the second criterion is to guard against rupture or failure and the third is to make sure that the material does not enter in to the accelerating tertiary creep stage which eventually leads to the failure of material. Since, minimum creep rate is related to rupture life (Monkman–Grant relation) and the time to onset of tertiary creep is also related to rupture life, it essentially narrows down to a single criterion, i.e. rupture criterion. It may be noted that in design, creep ductility is not considered while arriving at the allowable stress and this is one of the important issues that needs to be addressed.

At the Metallurgy and Materials Group, we have developed an original approach in terms of a new concept called ***time to reach Monkman-Grant ductility*** t_{MGD} (Fig. 1) which is defined as the time at which useful secondary creep strain (MGD) is exhausted and the true tertiary creep damage sets in. It is addressed at what time the creep damage that grows along the creep curve reaches a critical level. It is put forward that t_{MGD} is the time at which creep damage attains a critical level and this is shown for a typical case of cavitation damage mechanism in a-iron. Further, we deduce a critical damage criterion following CDM (continuum creep damage mechanics) and MPC–Omega (materials properties council) approaches, in terms of a universal relationship between t_{MGD} and t_r that depends only on the tolerance of a material to resist creep damage λ. The validity of the damage criterion is demonstrated for a wide range of materials from pure metals to complex engineering alloys. We also show that the proposed damage criterion has its useful implications to engineering creep design of high temperature components. Before we describe the critical damage criterion, it is in order to introduce briefly the creep damage tolerance factor λ, CDM and MPC – Omega approaches.

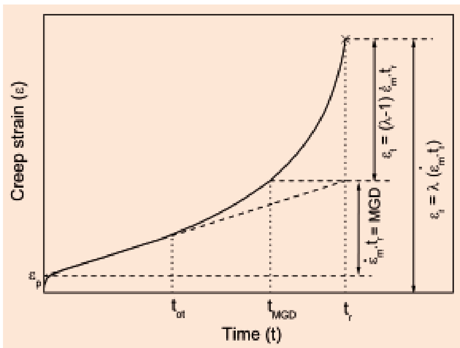


Fig. 1 Schematic creep curve with negligible primary creep strain ε_p illustrating time to reach Monkman-Grant ductility t_{MGD}, time to onset of tertiary creep t_{ot}, damage tolerance factor λ and limiting tertiary creep strain ε_t.

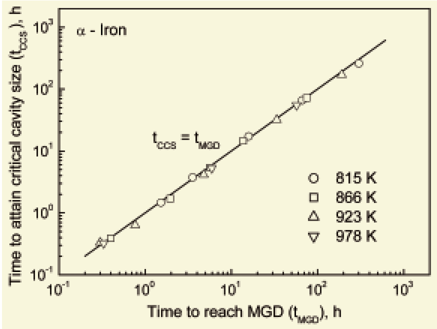


Fig. 2 Plot of time to attain critical cavity size t_{CCS} vs. time to reach Monkman-Grant ductility t_{MGD} demonstrating $t_{CCS} \approx t_{MGD}$ for creep cavitation micromechanism in α-Fe. Solid line is according to $t_{CCS} = t_{MGD}$ and symbols correspond to the experimental data.

The two well known approaches that describe the evolution of creep damage and its coupling to the deformation rate are CDM and MPC–Omega. According to CDM, the evolution of deformation and damage is expressed as two coupled differential equations in terms of an internal state damage variable. An important outcome of CDM is the creep damage tolerance factor λ which is defined as ratio of strain to failure ε_f to MGD (Fig. 1) i.e., $\lambda = \varepsilon_f/(\dot{\varepsilon}_m.t_r)$ and λ is a constant. For engineering alloys, its value ranges from 1 to about 20. It is a significant parameter that assesses the susceptibility of a material to localised cracking at strain concentrations and for engineering components, it is suggested to be a better measure of creep ductility as it is related to the ability of a material to redistribute the stresses. In simple terms, it is a measure of the tolerance of the material against creep damage; a large λ is desirable as the material can tolerate strain concentrations without local cracking. Thus λ is a material performance characteristic. According to MPC–Omega approach, creep rate $\dot{\varepsilon}$ from its initial value $\dot{\varepsilon}_0$ increases with strain ε as $\dot{\varepsilon} = \dot{\varepsilon}_0 \exp(\Omega_p \varepsilon)$, where Ω_p is reciprocal of MGD, i.e., $\Omega_p = 1/(\dot{\varepsilon}_m.t_r)$ for conditions showing negligible primary creep. The total damage coefficient Ω_p is the rate at which material's ability to resist stress is degraded by strain and is a material performance characteristic that is related to creep damage tolerance, i.e., higher the Ω_p, lesser is the resistance to creep damage. Creep damage can occur by various mechanisms such as loss of external cross section (with or without necking), loss of internal cross section (formation, growth and linkage of cavities at grain boundaries), degradation of microstructure (thermal-coarsening of particles, substructure-induced acceleration of creep) and gaseous-environmental attack (internal oxidation, failure of external oxide). Each damage micromechanism, when acting alone, results in a characteristic shape of creep curve and a correspondingly characteristic value of λ. For example, damage due to growth of cavities by coupled diffusion and power-law creep results in λ values between 1.5 and 2.5 whereas it can take as high as 10 or more when thermal-coarsening of particles cause damage.

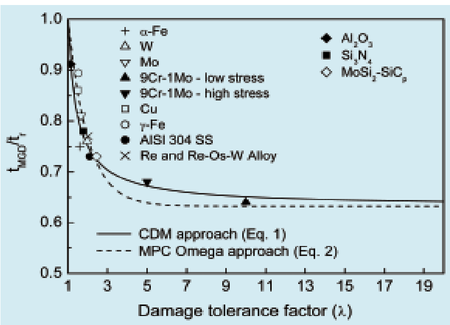


Fig. 3 Validity of critical damage criterion for various materials. Solid line is according to Eq. (1) based on CDM approach, whereas broken line is according to Eq. (2) based on MPC - Omega method. Symbols correspond to the f_{EXP} values obtained from double logarithmic plot of t_{MGD} vs. t_r for different materials.

In order to validate our proposition that for any damage mechanism, t_{MGD} is the time at which damage attains a critical level, mechanistic data as well as creep curves are needed, and such data are hard to find in the literature. The only published mechanistic data along with creep data that is available for α-iron was analysed in detail and t_{MGD} was determined for creep tests conducted at temperatures ranging from 815 to 978 K and at stresses ranging from 17.24 to 68.95 MPa. For this data, a two stage tertiary creep was observed and the end of first stage has been reported to correspond to the time at which cavities attain a stable critical size. The time to attain critical cavity size is designated as t_{CCS}. This means, the stage from t_{CCS} to failure corresponds to the growth of creep cavities and their linkage resulting in micro–cracks thus causing accelerated damage leading to failure. The plot of t_{CCS} vs. t_{MGD} (Fig. 2) shows that t_{CCS} matches well with t_{MGD} and validates our proposition that t_{MGD} is the time at which creep damage attains a critical level for the cavitation damage micro–mechanism. We like to extend such a validation for other damage mechanisms, but it has not been possible due to lack of detailed mechanistic data as well as the creep curve information. Further work in this direction is needed to establish firmly this proposition, but this involves extensive interrupted creep testing and microscopic examination. The creep damage criterion deduced according to CDM and MPC–Omega approaches is given in the following.

Using the relationship between strain fraction $\varepsilon/\varepsilon_f$ and time fraction t/t_r obtained from CDM approach (i.e., $\varepsilon/\varepsilon_f = 1 - [1 - t/t_r]^{1/\lambda}$) and by substituting the definitions of t_{MGD} and λ, the ***'critical damage criterion'*** in terms of a universal relationship between t_{MGD} and t_r is deduced as

$$\frac{t_{MGD}}{t_r} = 1-\left(\frac{\lambda-1}{\lambda}\right)^{\lambda} = \text{constant} = f_{CDM}\,. \qquad (1)$$

The key in the above equation is that though t_{MGD} and t_r vary, f_{CDM} is a constant independent of stress and temperature, since λ is a material constant in a given stress–temperature domain and for a specific damage mechanism. The above physically based Eq. (1) is termed as critical damage criterion because damage attains a critical value at t_{MGD}, when the criterion $t_{MGD} = f_{CDM}.t_r$ is met. Along the lines of CDM approach, the critical damage criterion based on MPC – Omega method is also deduced. Starting from the equation for any time t and t_r given in the MPC–Omega method (cf. Eq. (12) in M. Prager, J Press. Vessel Tech., 117, 1995, 95–103) and by inserting $\Omega_p = 1/(\dot{\varepsilon}_m.t_r)$, $\varepsilon_f = \lambda/\Omega_p$ and the condition of $\varepsilon = MGD = \dot{\varepsilon}_m.t_r$ at $t = t_{MGD}$ in this equation, the relationship between t_{MGD} and t_r in terms of λ can be easily deduced as

$$\frac{t_{MGD}}{t_r} = 1-e^{-1}+e^{-\lambda} = \text{constant} = f_{MPC}\,. \qquad (2)$$

Figure 3 shows the theoretical plot of t_{MGD}/t_r vs. λ following Eqs. (1) and (2), and further illustrates that t_{MGD}/t_r decreases with increasing λ saturating at 0.63 (i.e., $1–1/e = 0.63$) for large values of λ. Thus MPC–Omega method further strengthens the damage criterion obtained according to CDM approach [i.e., Eq. (1)] and reinforces that t_{MGD}/t_r depends only on λ. The f_{CDM} (or f_{MPC}) can be determined knowing the value of λ. In Fig. 3, $\lambda = 1$ corresponds to the situation where the material fails in the steady state regime without any tertiary creep. It is important to note that any change in the damage mechanism changes the value of λ that in turn changes the value of f_{CDM} (or f_{MPC}) and thus the mechanistically specific nature of the damage criterion is reflected through the value of λ. It can also be seen in Fig. 3 that when λ varies and for $\lambda > 4$, f_{CDM} (or f_{MPC}) remains almost constant indicating that for such conditions, Eq. (1) [or Eq. (2)] is applicable.

We demonstrate the validity of critical damage criterion for a wide range of materials. Results on 9Cr–1Mo ferritic steel and AISI 304 stainless steel obtained at IGCAR as well as published tensile creep data for various materials such as pure metals, ceramics and composite of intermetallic silicide were analysed for λ, t_{MGD} and t_r. λ was found to be constant for a given material and in the given stress–temperature domain. The constancy of λ is presented in Fig. 4 for 304 stainless steel, 9Cr-1Mo steel and for the published data on α-iron. The separate constant values of $\lambda = 10$ and 5 for low (873 K, 60–90 MPa) and high stress (793 K, 150–275 MPa and 873 K, 100–175 MPa) regimes, respectively for 9Cr–1Mo steel comes from different mechanisms of creep deformation and damage. For different materials, logarithmic plots of t_{MGD} vs. t_r obeyed $t_{MGD} \propto t_r$ (i.e., $t_{MGD} = f_{EXP}\, t_r$) and the observed f_{EXP} values are shown as symbols in Fig. 3 illustrating the validity of the damage criterion [i.e., Eqs. (1) and (2)]. The plot of t_{MGD} vs. t_r in Fig. 5 demonstrates the validity of damage criterion [Eq. (1)] for various materials and f_{CDM} values ranged from 0.65 for 9Cr-1Mo steel to 0.91 for Al_2O_3. Unlike in Fig. 3, the difference in f_{CDM} values is not seen in Fig. 5 due to logarithmic representation of the plot. It is important to emphasise that the damage mechanism specific nature of damage criterion comes through the value of f_{CDM} or f_{MPC} which is related to λ as any change in creep damage mechanism changes the value of λ.

The damage criterion has important implications to tertiary creep and engineering creep design. First implication is that t_{MGD} conceptually divides the creep curve into two parts as safe–unsafe regimes (Fig. 1) and this is something similar to plastic instability in tension dividing the stress-strain curve into uniform and non–uniform deformation regimes. In other words, it may be understood as the damage is homogeneous till t_{MGD} and it is beyond this time till failure is the region of localised creep damage. For creep curves obtained at different stresses and temperatures (i.e., with constancy of λ in a stress–temperature domain), the points on the creep curves corresponding to t_{MGD} can be joined to obtain the contour that satisfies $t_{MGD} = f_{CDM}\, t_r$. Then, the region below such a contour can be considered as the safe region, whereas above this (i.e., region from t_{MGD} to t_r) as the unsafe region governed by the accelerated growth of creep damage. The second is its importance to engineering creep design. The ratio t_{MGD}/t_r saturating to ~ 2/3 (Fig. 3) provides a physical basis for the factor of safety of 67 % employed on stress to cause rupture in 10^5 h to arrive at the design allowable stress. Further, as critical damage sets in and minimum creep ductility is assured up to t_{MGD}, it is appropriate that the stress to cause t_{MGD} in 10^5 h can be considered as a new design criterion. The proposed damage criterion also has its implication to Robinson's life fraction damage rule, which states that under non–steady stress and temperature conditions, failure occurs when $\Sigma\Delta t_i/t_{ri} = 1$, where Δt_i is the time spent at any given stress and temperature and t_{ri} is the rupture life under those conditions. When $\Sigma\Delta t_i/t_{ri}$ either equals or exceeds unity, it can be conveniently used as a conservative basis for life prediction. For situations when it predicts non conservative values of remnant life, i.e., when $\Sigma\Delta t_i/t_{ri} < 1$, a modified life fraction rule as $\Sigma\, \Delta t_i/t_{MGDi} = 1$ is proposed which is conservative. It can be shown that $\Sigma\Delta t_i/t_{MGDi} = 1$ leads to $\Sigma\Delta t_i/t_{ri} < 1$ as $t_{MGD} = f_{CDM}\, t_r$ (i.e., $\Sigma\Delta t_i/t_{MGDi} = (1/ f_{CDM})\, \Sigma\Delta t_i/t_{ri} = 1$ and $\Sigma\Delta t_i/t_{ri} = f_{CDM} < 1$), since it is reasonable to assume that the f_{CDM} remains constant (i.e., λ is constant) in a given stress-temperature domain. The conservative nature of the modified life fraction rule based on the concept of t_{MGD} has been validated for the published creep–rupture data on Hastelloy XR obtained under varying stress–temperature conditions. Thus, it is advocated that it may be more appropriate to redefine the creep design criterion in terms of t_{MGD} rather than rupture life.

(C. Phaniraj, B. K. Choudhary and Baldev Raj, Metallurgy and Materials Group)

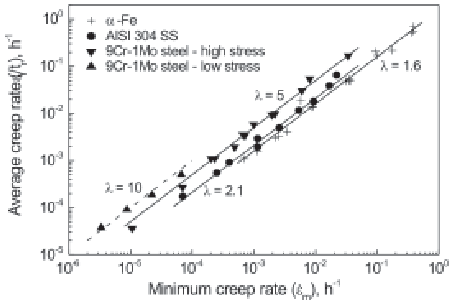


Fig. 4 Illustrates the constancy of λ for α-Fe, 9Cr–1Mo steel and AISI 304 stainless steel. λ is determined as the intercept at $\dot{\varepsilon}_m = 1$ in the double logarithmic plots of ε_f / t_r vs. $\dot{\varepsilon}_m$, since $\varepsilon_f / t_r = \lambda\dot{\varepsilon}_m$.

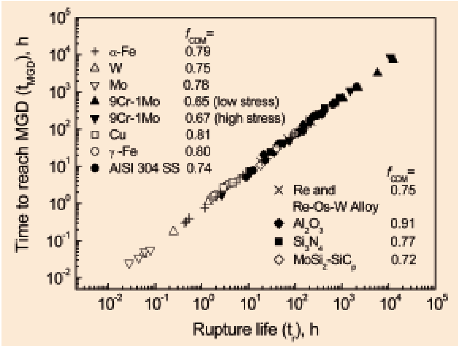


Fig. 5 Demonstrates the validity of critical damage criterion (Eq. 1) for different materials. The f_{CDM} values were calculated using the respective constant values of λ for various materials. Symbols represent experimental data obeying Eq. (1)

Forum for Young Officers

Corrosion behaviour of Ti-5%Ta-1.8%Nb alloy in Nitric acid medium for Fast Reactor Fuel Reprocessing Plant Applications

A. Ravi Shankar
(DOB: 01.07.1979)

Shri A. Ravi Shankar obtained his M. Tech degree (Materials & Metallurgical Engineering) from IIT, Kanpur in 2004. He joined Corrosion Science & Technology Division (CSTD), under DGFS scheme as Scientific Officer (SO/C) in September 2004.

A. Ravi Shankar and colleagues, Corrosion Science and Technology Division, Metallurgy & Materials Group

Titanium and its alloys exhibit superior corrosion resistance compared to conventional austenitic stainless steels for reprocessing plant equipment (eg. dissolver) where nitric acid of high concentration and temperature is used. Conventional austenitic stainless steels are sensitive to corrosion and several incidents of failures of such components are reported in reprocessing plants under such conditions. Titanium base alloys are preferable due to their excellent corrosion resistance, however, unalloyed Ti forms loose and hydrated oxide layers that dissolve preferentially in the condensed phase of nitric acid.

Ti-5%Ta-1.8%Nb alloy is being considered as a candidate material for dissolver in which nitric acid of high concentration and temperature is used. The alloy has been manufactured at NFC, Hyderabad and a flow sheet for fabrication has been established. The alloy was studied in different heat treatment conditions in order to determine the optimum microstructure for good corrosion resistance. The hot extruded and cold forged Ti-5%Ta-1.8%Nb alloy samples were initially given stress relieving SR (640°C\2 hrs\AC) treatment. Different heat treatments given to the samples were mill annealing MA (700°C\4 hrs\AC) and solution treatment ST (840°C\2 hrs\WQ). The solution treated samples were also subjected to aging AG (550°C\4 hrs\AC) and over aging OA (700°C\4 hrs\AC) treatment. The basic microstructure of this alloy after the heat treatments consisted of different proportions of equiaxed and acicular α, martensite (α′) and retained β phases.

Table 1

Average corrosion rate (in mpy) for five individual periods in the liquid, vapour and condensate phases of 11.5 M HNO_3.

Material / Condition	Corrosion rate in mpy		
	Liquid	Vapour	Condensate
304L SS	17.57	27.57	1.37
CP-Ti	6.26	0.52	11.02
Ti-5%Ta-1.8%Nb-MA	0.31	0.91	2.64
Ti-5%Ta-1.8%Nb-SR	0.32	0.94	4.24
Ti-5%Ta-1.8%Nb-ST	0.12	1.47	3.26
Ti-5%Ta-1.8%Nb-OA	0	0.55	2.03
Ti-5%Ta-1.8%Nb-AG	0.1	0	1.54

The corrosion behaviour of Ti-5%Ta-1.8%Nb alloy was studied using three phase corrosion test and potentiodynamic polarization tests in 11.5 M nitric acid in the above mentioned heat treated conditions. The exposed surfaces were examined by Scanning Electron Microscopy (SEM) and Auger Electron Microscopy (AES) in order to understand the morphology and nature of surface films formed. The results were compared with the behaviour of CP-Ti and 304L SS. For three phase corrosion test, samples were exposed to boiling liquid, vapour and condensate phases of 11.5 M Nitric Acid. The samples were exposed for a total period of 240 h. To observe the changes in the appearance and to measure the changes in the weight, the specimens were removed after every 48 hours, and fresh test solution was used for each period. This test done on three sets of similar material and similar heat treated condition to reduce experimental error. After completion of the test, the corrosion rates in individual periods and average corrosion rate for five periods were determined. The average variation in corrosion rate data was determined to be ±0.35 mpy.

The corrosion rates (in mpy) after five individual periods in the liquid, vapour and condensate phases of 11.5 M HNO_3 are shown in Table 1. For conservative assessment, the maximum corrosion rate obtained out of the three sets are considered and tabulated in Table 1. The corrosion rate of Ti-5Ta-1.8Nb alloy was lower than CP-Ti and 304L SS. The results showed that the corrosion rate in condensate phase was higher than that in boiling liquid and vapour phases of nitric acid for all heat treated conditions. The lower corrosion rate in the boiling liquid phase is due to the self inhibiting effect of Ti^{4+} ions in the liquid phase. On the other hand, continuous solution renewal in the condensate phase resulted in fresh nitric acid with lack of sufficient Ti^{4+} ions, which resulted in higher corrosion rate.

SEM micrographs of Ti-5Ta-1.8Nb alloy in MA condition in liquid, vapour and condensate phases are shown in Fig. 1(a), (b) and (c) respectively. SEM micrograph of Ti-5Ta-1.8Nb alloy in MA condition exposed to liquid phase indicates uniform corrosion, where as in vapour phase pit type of corrosion was observed. SEM micrograph of alloy in MA condition exposed to condensate phase indicates accelerated attack, confirming the continuous dissolution and high corrosion rate in condensate phase.

It is reported that corrosion resistance is deteriorated due to the presence of acicular morphology of α. The average corrosion rate for mill annealed, stress relieved and solution treated condition were found to be higher compared to the aged and over aged condition in all three phases. This has been ascribed to the presence of acicular morphology of α or α′ in the mill annealed, stress relieved and solution treated condition. The average corrosion rate for the aged and over aged condition was lower. This is attributed to the homogeneous microstructure and the presence of coarse equiaxed α and intergranular β enriched with Ta and Nb. The lower corrosion rate was evident from the SEM micrograph and EDAX analysis of the grain and grain boundary region proved the enrichment of Ta and Nb in the intergranular β.

Potentiodynamic anodic polarisation revealed good passivation properties for all heat treated conditions in 11.5 M nitric acid at room temperature as shown in Fig. 2. From three phase corrosion test results, the corrosion rate in liquid phase of nitric acid was found to decrease with time, whereas in the condensate phase continuous dissolution was observed. The AES spectra from the samples exposed to the liquid phase indicated the formation of non-conducting surface film. AES Spectra from the surface of unexposed and condensate exposed samples of CP-Ti were similar indicating the absence of protective film formation.

■

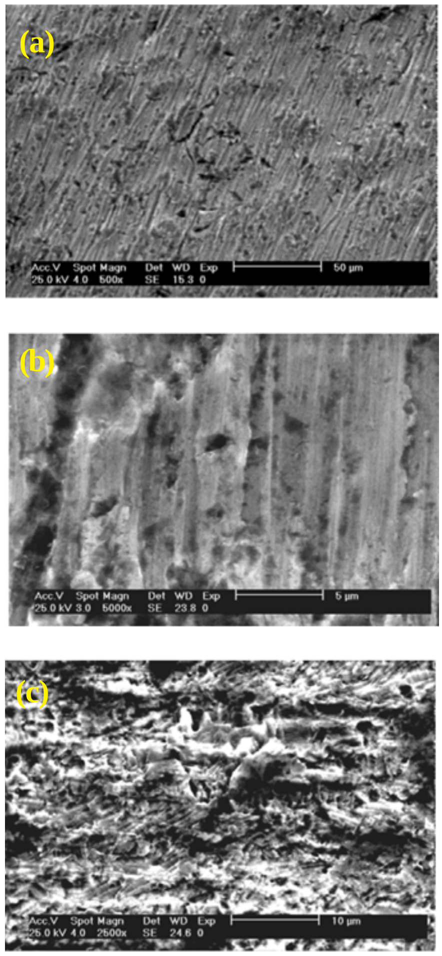


Fig 1. Scanning electron micrograph of Ti-5Ta-1.8Nb alloy samples in MA condition exposed to 11.5 M nitric acid in (a) boiling liquid, (b) vapour and (c) condensate phases.

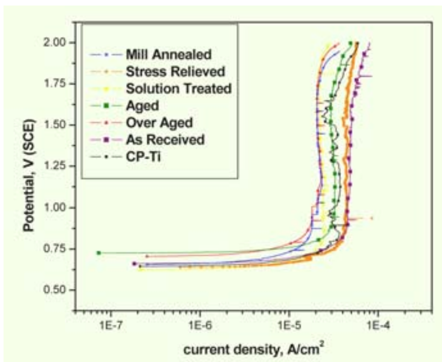


Fig 2. Potentiodynamic anodic polarisation of CP-Ti and Ti-5Ta-1.8Nb alloy in various heat treated conditions in 11.5 M nitric acid at room temperature.

Forum for Young Officers

Thermowell integrity analysis of PFBR – in line of MONJU failure

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(DOB: 19.09.1976)
Shri N. Animesh Pal obtained his B.E degree in Power Plant Engineering from Jadavpur University, Kolkata in 1999. He has joined the Mechanics and Hydraulics Division, Reactor Engineering Group as Scientific Officer (SO/C) in April 2005.

Animesh Pal and colleagues, Mechanics and Hydraulics Division, Reactor Engineering Group

In Fast Breeder Reactors, temperature measurement of sodium in pipeline is very important to know the healthiness of the system. Thermocouple housed inside thermowell is used to measure the sodium temperature. The thermowell protects the thermocouple from high velocity of sodium. For accurate temperature measurement, the thermowell tip should reach as close to the center of the pipe as possible. However, increase in the thermowell length enhances the risk of Flow Induced Vibration (FIV) of the thermowell. But, for sodium pipelines, which are well insulated, the radial temperature variation of sodium is minimal obviating the need for longer immersion lengths. FIV by vortex shedding is of two types viz. vibration in the drag direction (along the flow) and vibration in the lift direction (perpendicular to the flow). Drag frequency is twice that of lift frequency, but the amplitude of force in lift direction is higher. FIV failure can occur due to both the types. So, adequate care has to be taken for designing of thermowell, failure of which may have severe implications, as happened in the MONJU reactor of Japan.

The MONJU reactor was a major milestone in the Japanese national FBR development program. It attained initial criticality in April 1994 and started first generation of electricity in August 1995. In December 1995, approximately 750 kg secondary sodium leakage at the outlet of IHX (Intermediate Heat Exchanger) followed by sodium fire caused the reactor to shut down. On investigation, it was found that hot sodium leakage was due to breakaway of thermowell installed near the outlet of IHX as shown in Figs. 2

Table 1
Pipelines and Thermowell Lengths in PFBR

Pipe Line#	Pipe Inner Diameter (mm)	Thermowell Length (mm)
IHX O/L Line	542.8	180.9
SG O/L Line	386.4	128.8
SSP I/L Line	792.8	264.3
SGDHR – A Hot	211.0	70.3
SGDHR – A Cold	211.0	70.3
SGDHR – B Hot	211.0	70.3
SGDHR – B Cold	211.0	70.3

 # O/L – Outlet; I/L – Inlet; SG – Steam Generator; SSP – Secondary Sodium Pump

and 3. There was no adverse effect for the personnel and environment, as no release of radioactive material occurred. But, this incident was a major setback to the development of Japan's FBR program. After a detailed study, it was found that the thermowell failure resulted from fatigue damage due to high cycle FIV. The thermowell had a stepped configuration with sudden change in diameter, which is the cause for high stress concentration. This, compounded with high frequency oscillation in drag direction generated from symmetrical vortex shedding, caused thermowell failure in a short time. Moreover, the sodium leakage could not be identified at an early stage due to the absence of leak detector. Hence, sodium fire resulted due to reaction of hot sodium with air.

In PFBR (Fast Breeder Reactor Project), thermowells are provided in different systems viz. secondary sodium circuit and SGDHR (safety grade decay heat removal) lines for measurement of sodium temperature at different points. These thermowells are also subjected to FIV risks due to highly turbulent sodium flowing in these pipelines. The thermowells provided in PFBR, are compiled and listed in Table-1. One end of the thermowell is welded to the pipe wall while the other end is free and deep inside the sodium. All the thermowells have a uniform inner diameter of 15 mm and a tapered outer diameter of 30 mm to 22 mm from base to tip (Fig. 1). After a careful consideration of FIV risks without affecting measurement of bulk fluid temperature, thermowell length is optimized to be 1/3 of pipe diameter.

FIV analysis due to cross flow velocity of sodium, obtained from thermal hydraulic analysis, has been performed as per ASME Sec III Div 1 Appendix N. The thermowells are checked against vortex shedding and turbulent buffeting. The natural frequency of modes in drag and lift directions are obtained after considering the pipe flexibility. Lock-in range of frequencies, reduced velocity, reduced damping have been calculated using Finite Element Analysis computer code CAST 3M. It is found that lock-in synchronization is avoided for all the systems. All the thermowells satisfy vortex-shedding criteria. The response due to turbulent buffeting is found to be negligible for all the cases. So, all the thermo-wells are found to be safe against FIV risks.

Further, the alternating stress intensity is evaluated in the lift and drag directions. The alternating stress intensity in the governing lift direction with a stress concentration factor of 1.5 is 51 MPa, which is less than the allowable value of 83 MPa corresponding to 10^9 fatigue cycles. A fillet radius of 7.5 mm is recommended to restrict the stress concentration factor to 1.5. In addition to this, sodium leak detectors are provided in all the thermowells as an added precaution.

Hence, by adopting proper analysis and design methodology, it has been ensured that all the thermowells are free from FIV failure risks.

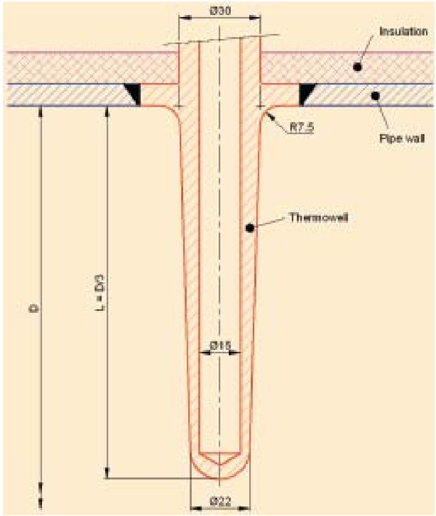


Fig.1 Recommended configuration of thermowell for PFBR (D = Pipe diameter, All dimensions in mm)

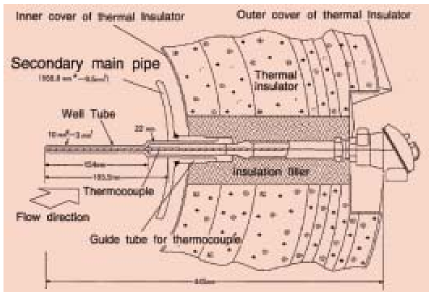


Fig.2 MONJU reactor thermowell arrangement

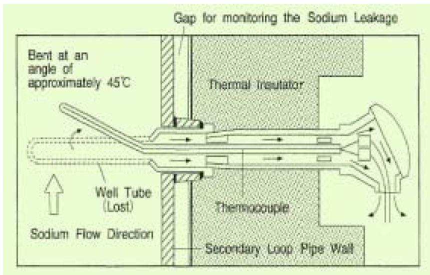
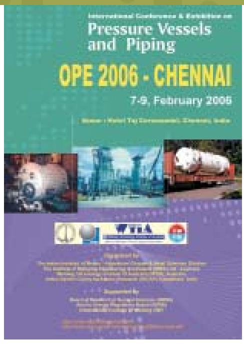


Fig.3 MONJU reactor thermowell after failure

Highlights of Symposia/Conferences



The International Conference & Exhibition on Pressure Vessels and Piping (OPE 2006 – CHENNAI) was held in Hotel Le Royal Meridien, Chennai, India during February 7-9, 2006. The conference was organised by The Indian Institute of metals (IIM) – Kalpakkam Chapter and Metal Sciences Division of The Indian Institute of Metals, The Institute of Materials Engineering Australasia (IMEA) Ltd. Australia, Welding Technology Institute of Australia (WTIA), Australia, Bharat Heavy Electricals Limited (BHEL) Tiruchirapalli, Larson & Toubro (L&T) Limited, Mumbai and Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, India. The conference was supported by Atomic Energy Regulatory Board (AERB) – Govt. of India, Board of Research in Nuclear Sciences (BRNS) – Department of Atomic Energy and International Institute of Welding (IIW). OPE 2006 - CHENNAI received excellent response and support from Indian Industry. The conference was actively participated by over 600 delegates which includes 76 overseas delegates and a large participation from Industry. The countries (19 including India) participated in the conference include Australia, Czech Republic, Finland, France, Germany, Hungary, India, Iran, Israel, Italy, Japan, Kyrgyz Republic, Poland, Portugal, Russia, S. Korea, The Netherlands, UK and USA.

The delegates were welcomed by Dr. K. Bhanu Sankara Rao, Chairman of Kalpakkam chapter of The Indian Institute of Metals. Mr. Chris Smallbone, President, International Institute of Welding inaugurated the conference. Dr. Baldev Raj, Distinguished Scientist and Director, Indira Gandhi Centre for Atomic Research, Kalpakkam presided over the function. A special lecture on the "*Perspectives of International Collaborations in the area of Pressure Vessels & Piping*" was delivered by Dr. R. Viswanathan, Technical Executive - Materials Application, Electric Power Research Institute, USA. Prof. John W. H. Price of Monash university, the founder and architect of this conference in Australia described the organisational efforts of OPE 2006 – CHENNAI as phenomenal and shared his experience detailing the "*Present and Future Perspective of OPE*" in his address. The souvenir and the proceedings (CD) were released by *Prof. John Price* on this important occasion. The Technical Exhibition was inaugurated by Mr. M. Anbunathan, Chief Controller of Explosives, Petroleum and Explosives Safety Organisation, Nagpur, India. Finally, the "vote of thanks" on the occasion was delivered by the Convenor of the conference, Dr. B. K. Choudhary of Indira Gandhi Centre for Atomic Research Kalpakkam, India.

The three days technical deliberations were structured in plenary (3 sessions), parallel (28 sessions) and poster sessions. Eminent speakers of international standing delivered Plenary and Invited lectures in their areas of chosen speciality that was of pertinence to the subject of the conference. A total of 250 technical papers were presented. Out of this, 6 were plenary, 59 were invited lectures and the remaining were contributory papers.

In order to conclude the gains and learning from the intense three days technical deliberations during OPE 2006 – CHENNAI and for providing certain useful and necessary directions for future work in the area of pressure vessels and piping, a valedictory session was organised. Dr. Baldev Raj as Chairman and nine eminent personalities of the world from different areas related to the theme of conference formed the panel of experts. Dr. Baldev Raj, Chairman, OPE 2006 – CHENNAI in his address appreciated the wonderful presentations by the specialists and the authors, and highlighted the gains from the three days proceedings of the conference. He also appreciated the participants for sharing the information with clarity, alacrity and openness and suggested that all efforts will be made to publish the papers in four or five volumes of books/journals. Though all the aspects of pressure vessels are important, but the panel focused on few very important issues such as a) Design with new materials b) Economics c) Safety, Innovations d) Life Management and e) Human resources. Dr. Baldev Raj concluded the valedictory by announcing the next OPE conferences that would be held in Australia in 2008 followed by India in 2010.

(Reported by B.K. Choudhary, Secretary, OPE-2006)

6th Quality Circle Awareness Day – 2006

Quality circle (QC) is a novel concept which is prevalent in the industry to improve the organizations and working environment among the people. In IGCAR, Quality Circle Awareness Day (QCAD) programme is being conducted every year.

This year the QCAD programme was conducted for two days on 24th and 25th July 2006. The programme was inaugurated by Director, ROMG, and Chairman Apex Steering Committee on Quality Circle (ASCQC). Shri A. Justin, Senior manager, Human Resources, M/S Ashok Leyland, Chennai has delivered an inspiring key note address.

Totally twenty quality circles (about 140 members) from Central Workshop Division, Auto Shop, Quality Assurance Division, Engineering Services Division, Fast Reactor Technology Group, Reactor Operations & Maintenance Group, Hospital, General Services Organization,

Chemical Group, and Schools have presented the case studies in a wide spectrum of topics covering Technical, Research &Development, Services and Education.

In addition to the participants, members of the newly formed QC and personal from other groups numbering around 60 have attended the programme as delegates. Among the twenty QC fourteen were adjudged as outstanding / distinguished / meritorious presentations.

Professional judges from M/S BHEL, M/S Ashok Leyland have assessed the case studies and also gave guidance to the QC members and motivated them. The enthusiasm shown by all the participants and the delegates is expected to motivate the personal from other divisions in forming the new Quality Circles.

Reported by A.S.L.K.Rao, Member Secretary, ASCQC

Highlights on 6th International Trade Fair & Conference on Minerals, Metals, Metallurgy & Materials - IIM Diamond Jubilee Celebrations- Pragati Maidan, New Delhi, September 11-14, 2006

Honourable Union Minister of state for Commerce and Industry Dr. Jairam Ramesh handing over the Commendation Award to Shri Daniel Chellappa, IGCAR and Shri Atul Bajpai, DAE, who received it on behalf of the DAE during the Valedictory function.

IGCAR participated in the prestigious DAE pavilion at the 6th International Trade Fair on '*Minerals, Metals, Metallurgy & Materials*' organized by the Indian Institute of Metals (IIM) as part of its diamond jubilee celebrations at Pragati Maidan, New Delhi during September 11-14, 2006. The expo and the concurrently conducted IIM Conference on the theme "Unleashing India's Potential in Metals & Minerals" were inaugurated by His Excellency Shri. Bhairon Singh Shekhawat, Vice-President of India. Dr.T.Subbarami Reddy and Dr.Akhilesh Das Hon'ble Union Ministers of State for Mines and Steel were the guests of honour. First book in the series of Metallurgy and Materials Science books, initiated by IIM, entitled '*Advances in Materials Characterization*' edited by Dr. G. Amarendra and Dr. Baldev Raj of IGCAR, India and Prof. M.H.Manghnani of USA was also released by the Honourable Vice-President on this occasion.

IGCAR had showcased its breakthroughs and achievements in the indigenous research and development of the fast breeder technology, especially in the domains like materials and metallurgy. The panels displayed included the benchmarks and national & international records set by BHAVINI too. Hand-outs on the multi-disciplinary programmes of IGCAR and the booklet on 'Energy security for India – A challenge to material scientists and technologists' authored by Dr. Baldev Raj, Director IGCAR were distributed to the inquisitive visitors to the IGCAR section. Besides IGCAR, five other units of DAE viz. BARC, IRE, NFC, AMD and HWB also participated in a big way.

The fair had a very strong global presence with the participation of technological giants from Europe, Asia and North America. The competing leading houses in India such as SAIL, Tata Steel, GSI, BIS, M.N.Dastur, BEML, Essar Steel, Llyods Corporation, NALCO, RINL, Vedanta Resources Plc, Jindal Steel & Power, NMDC, also participated. The four days expo attracted in large numbers the policy & decision makers, CEOs, government authorities, engineers, scientists & professionals, key personnel from core & allied industries and R & D institutions, technology developers, trade delegations, equipment manufacturers & suppliers, energy managers, environment specialists, financial institutions besides the general public, students and the media.

The jury of eminent personalities duly constituted for selecting the best exhibitors for the 'Technology in Minerals, Metals, Metallurgy & Materials' Award category commended the DAE's display of expertise and strength, and the Commendation Award was given away by Dr.Jairam Ramesh, Hon'ble Union Minister of State for Commerce & Industry during the Valedictory and Awards Function, in the august presence of Dr.A.K.Rath and Shri.Pradeep Kumar Additional Secretaries to the Government of India in the Steel and Mines Ministries.

Reported by
J. Daniel Chellappa and P.V.Ramalingam,
Public Relations Committee

International Symposium on Advances in Stainless Steels (ISAS-2007)

April 9-11, 2007, Chennai, India

ISAS 2007 is jointly organized by The Indian Institute of Metals (IIM) Kalpakkam Chapter, Metal Sciences and Ferrous Divisions of IIM, Board of Research in Nuclear Sciences and the Indira Gandhi Centre for Atomic Research, Kalpakkam at Chennai during April 9-11, 2007.

Topics to be covered at the symposium comprises of : (i) Austenitic, ferritic, martensitic, precipitation hardening and duplex stainless steels, (ii) New and special grades of stainless steels, (iii) Production of stainless steels (Casting and Wrought Products), (iv) Powder metallurgy of stainless steels and products , (v) Production of stainless steel welding consumables, (vi) Physical metallurgy of stainless steels and welds, (vii) Mechanical properties of wrought products, castings, and weldments of stainless steels, (viii) Role of trace and tramp elements on the properties of stainless steels, (ix) Design aspects, codes and standards for stainless steel components, (x) Modeling and Structural integrity assessment of stainless steel components, (xi)Welding processes and weldability of stainless steels, (xii) Corrosion aspects of stainless steels, (xiii) Non-Destructive Testing of castings, wrought products and welded components, (xiv) In-service inspection of stainless steel components, (xv) Residual stresses and distortion in fabrication of stainless steel components, (xvi) Heat treatment of stainless steels, (xvii) Surface engineering of stainless steel components, tribology and wear, (xviii) Failure analysis of stainless steel components, (xix) Global marketing.

Papers are invited on the topics outlined above and other subjects of interest to the theme of the symposium. Abstracts of about 250 words should be submitted to the convenor latest by 15th December 2006.

For further information please contact :
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Historical event of the commencement of

Training School at IGCAR

History being created – Dr. Baldev Raj, Director, accompanied by Mrs. Baldev Raj with the first batch of engineering trainees, standing in the front of the Statue of Dr.Raja Ramanna. Also seen in the photo are Dr. M. Sai Baba, Dr. G. Venugopal Rao and Dr. Vidya Sundararajan of Strategic & Human Resources Planning Section (S&HRPS).

So as to meet the urgent and growing need of scientific human resources with the right training and emphasis on Science & Technology of Fast Reactors and associated fuel cycle facilities, the need for Training School for fresh engineers at IGCAR has been felt for a long time. Due to immense interest and proactive steps taken by Dr. Baldev Raj, Director, IGCAR and the encouragement and support from Dr. Anil Kakodkar, Chairman, AEC, this has become a reality.

The inaugural function of IGCAR Training School was held on September 8th 2006 at the Ramanna Auditorium, IGCAR. The program started with the welcome address by Dr. M. Sai Baba, Head, S&HRPS. Dr.Baldev Raj, Director, IGCAR formally inaugurated the school highlighting the opportunities available to the trainees to contribute to various programmes of the department and also dwelt upon the guidelines to be adhered to take the training school to international standards.

Initially, the training programme will be conducted in three disciplines (viz.) Mechanical, Electronics & Instrumentation and Chemical engineering. The training school at IGCAR is affiliated to BARC training school. The school has started functioning at the Safety Research Institute building of AERB at Kalpakkam with 22 engineers. The faculty for teaching has been drawn from the eminent Scientists and Engineers working at IGCAR and a few others from outside. ***(M. Sai Baba, S&HRPS)***

AWARDS AND HONOURS

Dr. Baldev Raj has been elected to the Board of Directors of the International Institute of Welding. He has also been elected as a Fellow of Third World Academy of Sciences (TWAS).

The Indian Nuclear Society (INS) Award for the year 2005 has been given to **Dr. P. Chellapandi,** REG.

The INS Medals for the year 2005 have been conferred on **Dr. B. Venkataraman, ESG and Dr. Shaju K. Albert,** MMG.

Dr. C. S. Sundar, MMG, has been awarded the MRSI-ICSC Superconductivity & Materials Science Annual Prize for the year 2007.

Mrs. C. Sudha of Physical Metallurgy Section, MMG has won the Shri. Ram Arora Award for the year 2007.

DAE Exhibition pavilion, put up during 6th International Trade Fair and conference on “Minerals, Metals, Metallurgy & Materials” commemorating the IIM Diamond Jubilee celebrations during September 11-14, 2006 has won *the Commendation Award* for showcasing the products, technologies and services.

Dr P.R.Vasudeva Rao, Chairman, Editorial Committee Members: Dr.G.Amarendra, Shri M.Ganapathy, Dr.K.V.G.Kutty, Dr.Mary Mohankumar, Shri G.Padma Kumar, Shri Shekar Kumar, Shri M.Somasekharan, Shri R.Srinivasan, Shri R.V. Subba Rao, Shri K.V.Suresh Kumar. Published by Scientific Information Resources Division, IGCAR, Kalpakkam - 603 102