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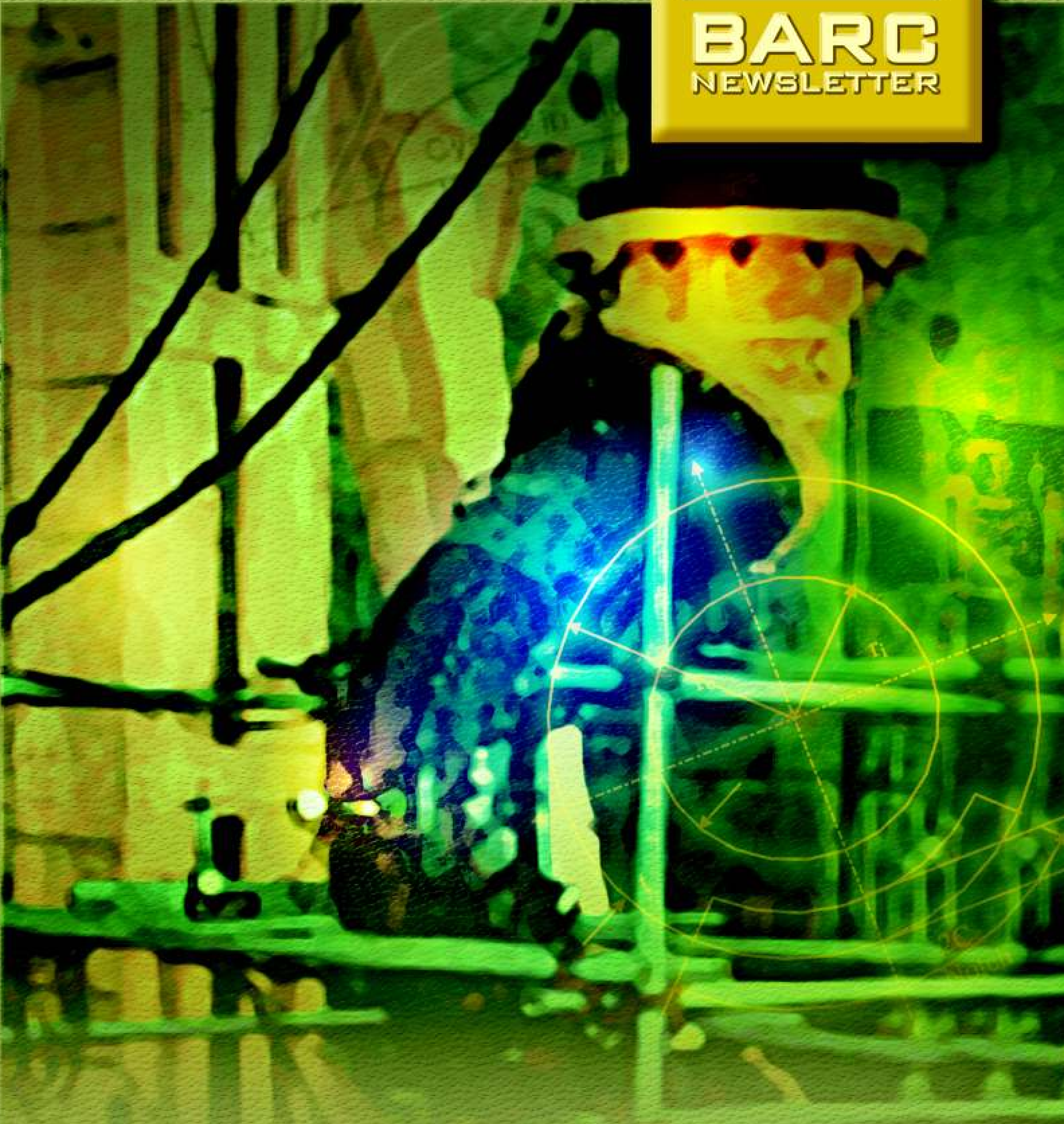
बीएआरसी न्यूज़लैटर
BARC NEWSLETTER



IN THIS ISSUE

FATIGUE STUDIES ON CARBON STEEL PIPING MATERIALS AND COMPONENTS: INDIAN PHWRS

In the next issue

Separation of high purity rare earth elements for nuclear applications

In PHWRs as well as in the proposed AHWR, Boron can be used for nuclear reactor control applications. But Boron has certain disadvantages, which can be overcome, through the use of rare earth elements, such as Gadolinium and Dysprosium. In fact, Gadolinium nitrate (Gd $(NO_3)_3 \cdot 6H_2O$) is already being used in TAPS 3 & 4 for reactivity control and reactor shutdown operations. Dysprosium Oxide is proposed to be used in AHWR. Terbium, is a vital component of luminescent phosphors such as $Gd_2O_2S : Tb^{3+}$ which have been developed at REDS.

The separation of the above three rare earth elements, from various mixed oxide feed stocks is described in this article. The Solvent Extraction (SX) process, which involves a number of separation stages and is accomplished through a complex process circuit, is also described in this article.

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FATIGUE STUDIES ON CARBON STEEL PIPING MATERIALS AND COMPONENTS: INDIAN PHWRS

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Introduction

The design of engineering components and structures is based on material properties, obtained from monotonic tensile tests. However in service, repeated thermal stresses are generated, due to expansion and contraction as a result of temperature gradient, which occur because of heating and cooling during start-up, shut down and thermal transient condition. This phenomenon of thermal cycling is termed as Low Cycle Fatigue (LCF). The expansion and contraction in the piping system due to thermal gradient, leads to strain cycling resulting in LCF damage, in the piping system. Therefore, it is important to consider the Low Cycle Fatigue (LCF) and cyclic stress-strain behavior of the material, in the design and integrity analysis of the structural components, subjected to plastic deformation at room and operating temperatures.

In a more general view, the localized plastic strains at notch, subjected to either cyclic stress or strain, result in strain controlled conditions near the root of the notch, due to the constraint effect of larger surrounding mass of essentially-elastically deformed material. Since plastic deformation in materials is not completely reversible, modification to the structures occurs during cyclic straining, which can give rise to changes in stress-strain response due to thermal cycling. Therefore, cyclic stress strain of the material, differs from the monotonic and needs to be evaluated.

Failure of piping components under normal operating conditions, well below the allowable stress given by codes, can often be attributed to flaws. Such failures show, that conventional stress analysis is not sufficient, to guarantee component integrity under operational conditions. Welding is one of the widely used fabrication processes in the piping system of nuclear power plants. Although utmost care is taken in following various standards to produce defect-free weld joints, some defects may be undetected during inspection at the time of welding, due to either limitation of the inspection system or human error. Fatigue is one of the mechanisms, considered active in the piping system, which may lead to crack initiation, either from the highly stressed regions or the undetected flaws or the heterogeneity in the weld material of weld joints. Therefore, it is desirable to confirm that crack initiation due to cyclic loading, will not occur during the service period of the reactor. Behavior of initiated cracks (i.e. crack growth) under cyclic loading, for accurate prediction of life of the component, is also of concern to most of the older nuclear power plants.

The current Leak Before Break (LBB) assessment procedure is described in USNRC guide [1]. LBB is ensured by demonstrating three levels of safety assessment against sudden Double-Ended Guillotine Break (DEGB). Level 1 is inherent in the design philosophy of ASME Section III, which is normally followed in piping design. Level 2 requires postulating a surface crack mostly in the weld and shows that there is insignificant crack growth of this surface, during the entire life period of the reactor. From operating experience of PHWRs, it has been observed, that under controlled environment of primary heat transport piping system, fatigue is the only mechanism, which cannot be ruled out. Level 3 requires postulating throughwall crack at the maximum stress region, with the most unfavorable material properties and shows that this crack will withstand maximum load that may act during safe shutdown earthquake event. Level 2 assessments for LBB require evaluation of fatigue crack initiation and crack growth rate.

In the past, fatigue crack initiation was studied, using notched small specimens by evaluating local stress or strain at the notch tip, considering the stress or strain concentration, equivalent energy density method and Low Cycle Fatigue (LCF) curve [2]. Paris Law has been used for evaluation of Fatigue Crack Growth Rate (FCGR) using constants derived from Compact Tension (CT) or Three Point Bend (TPB) specimens, following the ASTM E647 [3]. The ASME Boiler and Pressure Vessel Code Section XI also gives the FCGR curve for air and water environments for carbon and low alloy ferritic steels [4], based on small specimens. The effects of stress ratio on the fatigue crack growth behaviour are widely available for standard specimens [5]. This crack growth data obtained from CT or TPB specimens, are conveniently used for prediction of crack growth in surface flawed components, assuming that surface flaw attains a semi-elliptical shape during growth, crack growth rate is independent of the states of direction and stress.

In view of this, the Reactor Safety Division initiated a component test program, to understand, demonstrate and verify the issues, related to design, safety and life extension of piping components. In this programme, pipes and elbows were procured as per specifications and requirements of the primary heat transport system piping of Indian PHWRs. Welding of the pipes was carried out as per the general requirements of ASME Section IX and the acceptance criteria of ASME Section III. Additional requirements specified by NPCIL for Indian nuclear power plants were also followed. All the tests (LCF and FCGR) on small specimens were carried out as per procedure of the ASTM standards. Actual pipe, pipe weld and elbows with surface notch were used for component tests.

This article describes the results of fatigue studies on carbon steel piping materials and components of Indian PHWRs. Tests on actual pipes and elbows with part through notch were carried out, to study the behaviour of crack growth under cyclic loading for different pipe sizes, notch aspect ratios, stress ratios etc. In conjunction with component tests, experimental studies were also conducted on standard specimens to understand the effect of different variables such as size (thickness), type of specimen and components (elbow and pipe), welding, stress ratio, notch orientation on fatigue crack growth rate. The analytical predictions for crack initiation and crack growth for the tested components were compared with experimental results. In all, 80 specimens and 28 components were tested under this programme with the following objectives:

- Generation of low cycle fatigue curves and fatigue crack growth rate database for piping material.
- Demonstration of Level II, Leak Before Break design criteria showing that if there is flaw/ defect, there will be insignificant crack growth during the operating life of the plant.

- To show that crack grows more rapidly in depth (thickness) direction as compared to surface (circumferential) direction. This is essential for verification of Level II, LBB.
- Applicability of FCGR data generated from the specimens in the design and analysis of the component.
- To understand the effect of various parameters such as base and weld, orientation of notch, product form, thickness, stress ration etc. on FCGR.
- To verify the existing analytical procedure for the prediction of fatigue life of the flawed components.

We require our own component integrity test programme considering the fact, that fatigue behaviour of the piping system is dependent on the material, fabrication process, geometry and degradation mechanisms encountered in the piping system. The studies carried out on actual materials and components will help in reducing the factor of safety. Reduction in safety factor will lead to lowering of cost of construction of the plants. Remaining life of the component can be accurately predicted.

Experimental Programme

Materials

Studies were carried out on seamless pipes of SA333 Gr.6 and elbows of SA420 WPL6 material used in Indian PHWRs. The pipes and elbows were in the normalized and tempered condition conforming to specifications of ASME Section II [6] and Section III.

Welding of pipes was carried out as per guidelines given in section XI of the ASME code. Additional requirements specified by NPCIL were also followed. The Gas Tungsten Arc Welding (GTAW) process was followed, for root pass and the second pass and Shielded Metal Arc Welding (SMAW) for the remaining passes. ER-70S-2 welding rod was used, for GTAW and E-7018-1 electrode for SMAW. After completion of welding, post weld heat treatment was carried out, to relieve stresses introduced during welding.

The measured chemical composition and tensile properties of the pipe and pipe weld material are detailed in a paper by the author [7]. Fatigue tests were conducted on specimens and components (pipes and elbows). A brief summary of tests conducted under this programme is discussed below.

Component and Specimen Testing

Fatigue crack growth analysis in flawed components requires FCGR data, which is usually evaluated using CT or TPB specimens and expressed as Paris law. FCGR in component and specimens may differ because of difference in the stress ahead of their crack tip. Range of DK obtained from the specimen tests are lower as compared to that of components for a given stress range. Therefore, extrapolation or suitability of Paris law constants for higher ranges of DK is also one of the issues to be resolved. In view of this, we plan to carry out studies on components and specimens.

Specimen Testing

Specimen testing was conducted, to determine the basic cyclic stress strain curve, Low Cycle Fatigue (LCF) and Fatigue Crack Growth Rate (FCGR) properties. In addition to this, transferability (specimen data to component) and extrapolation (for higher crack growth and ΔK) of crack growth data are the issues, which need to be resolved.

- Low Cycle Fatigue: Tests were conducted on standard uniaxial specimens under strain-controlled condition in which strain range (Δe) was varied from 0.4 to 3.0 %. In all, 40 specimens were tested. The outcome of these tests was cyclic stress strain and low cycle fatigue curve. These properties were used, for assessment of crack initiation life of the notched component.

- Fatigue Crack Growth Rate: Tests were conducted on CT and TPB specimens. The location of machine with respect to pipe is shown in Fig. 1a. The outcome of these tests was the material constants of Paris law. About 50 specimens were tested, to understand the effect of different parameters on FCGR:

  a) Specimen type: CT and TPB, these specimens were selected to understand the effect of constraint on the FCGR because the state of stress ahead of crack tip is different. Both the specimens are acceptable as per ASTM standard.

  b) Stress ratio: (R=Minimum load / Maximum load): 0.1, 0.3 and 0.5. Varying stress ratio was considered, to understand the effect of crack closure.

  c) Base and Weld: Specimens were machined from pipe base and pipe weld.

  d) Thickness of specimen: Specimens were machined from different sizes of pipe, that is 10 mm, 15 mm and 20 mm from 219 mm, 324 mm and 406 mm outer diameter respectively.

  e) Product form: Specimens were machined from seamless pipe and pipe bend (elbow)

  f) Notch orientation: Specimens were machined in two orientations namely LC and CL. The notch is in longitudinal direction with respect to the pipe in CL orientation, whereas it is in circumferential direction in LC orientation.

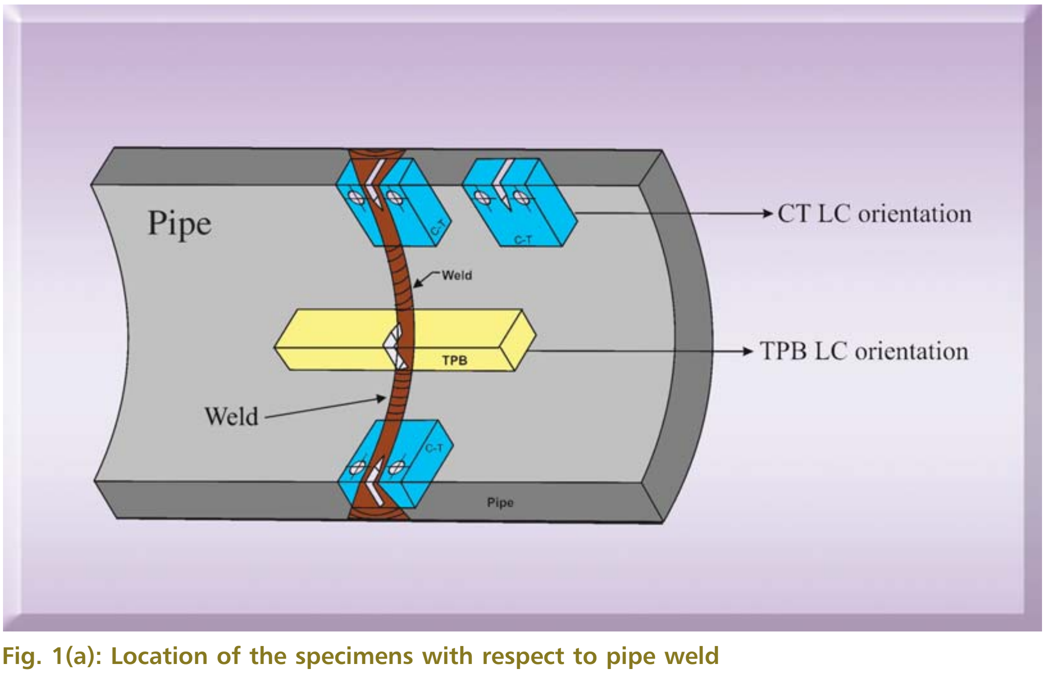

Fig. 1(a): Location of the specimens with respect to pipe weld

Component Testing

Fatigue crack growth studies were conducted on pipes and elbows with pre-machined notch. In all, 28 tests were conducted to cover the effect of the following variables:

a) Component type and size: Component type is pipe and elbow. Three pipe sizes tested were of outer diameters, 219 mm, 324 mm and

406 mm, which are designated in this paper as 200NB, 300NB and 400NB, respectively. The corresponding thickness are 15 mm, 22 mm and 26 mm. Elbow size tested was 90° short radius of 219 mm outer diameter and 15.1 mm nominal wall thickness.

b) Stress ratio (R=Minimum load / Maximum load): 0.1and 0.5.

c) Pipe and pipe weld: Tests were conducted on seamless pipes with initial notch in pipe base and girth welded pipe with notch at weld location.

d) Notch size or notch aspect ratio: Notch length (2C), Notch depth (a/t) range covered was 0.13 to 0.4 and aspect ratio (2C/a) varying from 11 to 57. This was considered to better understand the evolution of flaw shape under cyclic loading. Notch shape and the nomenclature are shown in Fig. 1(b).

e) Notch location: In elbow tests, the notch was machined at crown and intrados.

Schematic and actual test set up for pipes are shown in Figs. 2(a) & 2(b), for elbow in Figs. 2(c) & 2(d). The support system for pipe test consists of two pedestals with two rollers, which provides four-point bending. This type of loading ensures, that the mid section of the specimen, where the notch is located, is subjected to pure bending.

Tests were carried out at room temperature and air environment under load control mode using sinusoidal

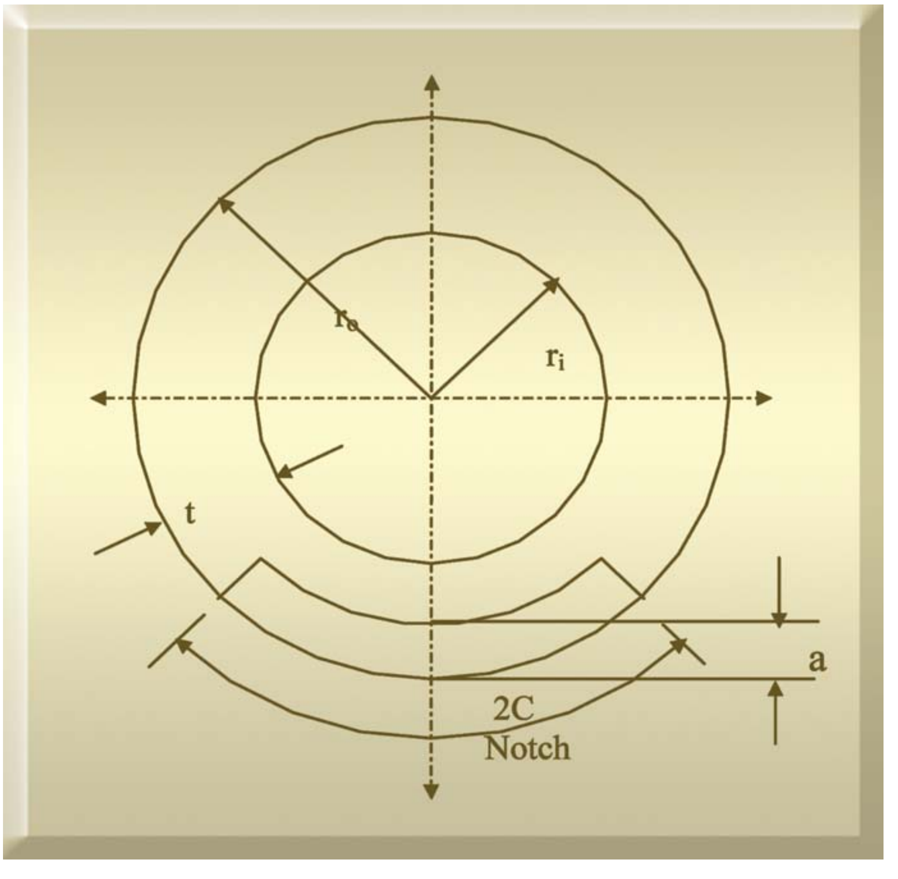

Fig. 1(b): Pipe cross section of notch plane with circumferential, rectangular, external surface crack

waveform loading with constant amplitude. The cyclic loading frequency was kept in the range of 0.5 to 1.0 Hz.

Low Cycle Fatigue (LCF)

Cyclic stress-strain and LCF properties were evaluated according to the procedure given in ASTM E606 standard [8]. The specimen (diameter 4.5 mm) was machined from the 400 mm outer diameter pipes and is shown in Fig. 2(e). Tests were conducted under fully reversible condition for different strain ranges at room and operating (288° C) temperatures and air environment. The LCF curves for room and operating temperature

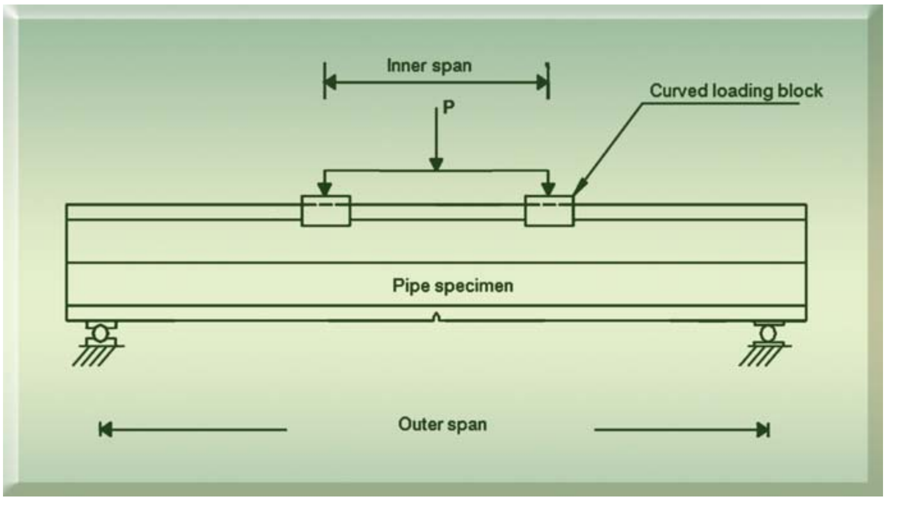

Fig. 2(a) : Schematic set up for pipe test

Fig. 2(b) : Actual set up for pipe test

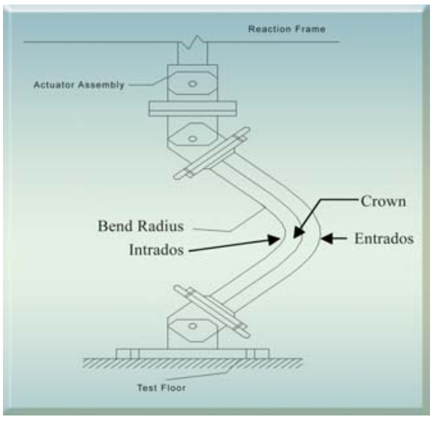

Fig. 2(c) : Schematic set up for elbow test

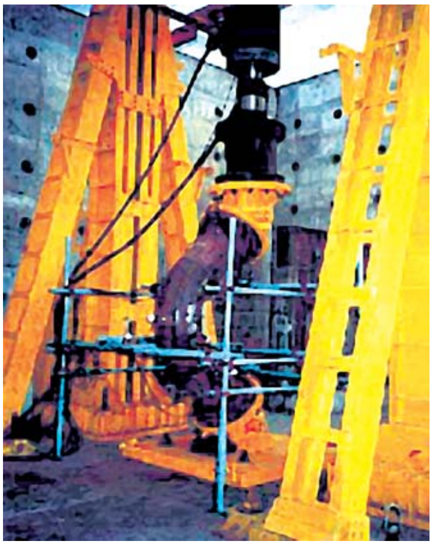

Fig. 2(d) : Actual set up for elbow test

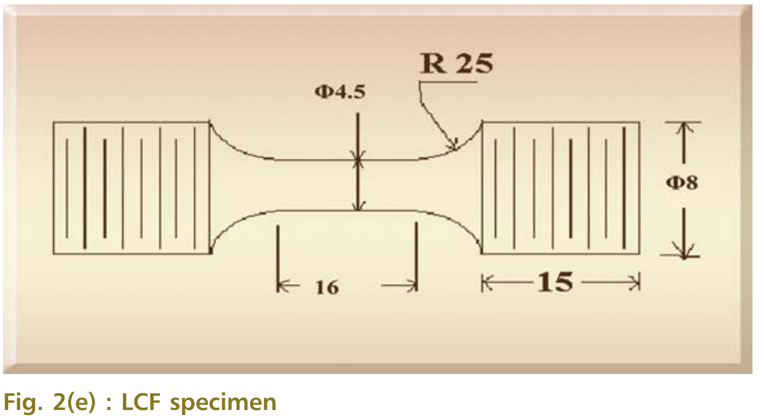

Fig. 2(e) : LCF specimen

are given in Fig. 3. The cyclic stress strain curve can be represented by equation (1) and LCF curve by equation (2).

$$\Delta\varepsilon/2 = 100/E \times (\Delta\sigma/2) + (\Delta\sigma/2k)^{1/n} \quad (1)$$

$$\Delta\varepsilon/2 = \sigma_f¢ /E\ (2N)^b + \varepsilon_f'\ (2N)^c \quad (2)$$

Where, $\Delta\varepsilon/2$ is total strain amplitude (%), $\Delta\sigma/2$ is total stress amplitude (%), 2N is number of reversals (one cycle consists of two reversals), N is number of cycles to failure, σ_f' is Fatigue strength coefficient, e_f' is fatigue ductility coefficient, b is fatigue strength exponent, c is fatigue ductility exponent, E is Young's Modulus in MPa.

Values of constants in above equations as evaluated from tests are given in Table 1.

Material undergoes cyclic strain hardening which is more pronounced at operating temperature. The attainment of maximum stress is also faster at 288°C as compared to room temperature. The cyclic hardening rate for this type of steel can be attributed to interaction between dislocations and solute atoms. Solute atoms in the material cause obstruction to the movement of dislocations and to maintain the strain rate with continued cycling, dislocations are generated continuously. The generation of more dislocation results in increase of dislocation density, which leads to increase in stress. LCF properties have been observed to be superior at room temperature than at 288°C for low strain ranges. whereas properties are almost identical at higher strain ranges. This is consistent with the fact that serrations were observed, in hysteresis loop, for strain amplitude above ± 0.5% and

Table 1: The values of fatigue curve constants and cyclic stress strain curve constants

Strain ratio	Temperature (°C)	σ_f'	ε_f'	b	c	n	K
0	28	91207	47.97	-0.1283	-0.5551	349.9	0.1766
-1	28	58606	24.06	-0.0757	-0.4814	354.27	0.1523
0	288	50727	21.15	-0.0454	-1.004	360.46	0.04865
-1	288	966240	127	-0.0049	-0.7150	358.27	-0.00575

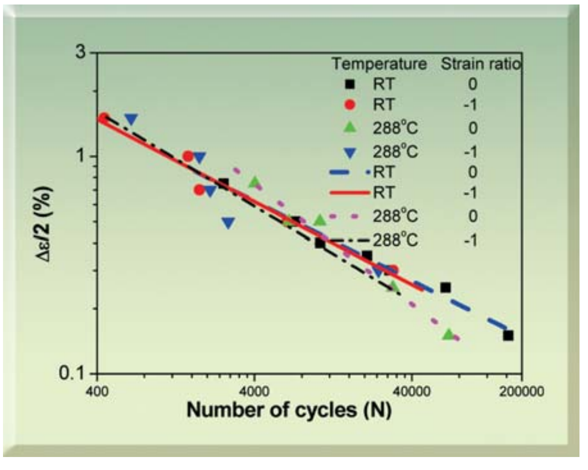

Fig. 3: Comparison of fatigue life vs total strain amplitude for different strain ratio temperatures

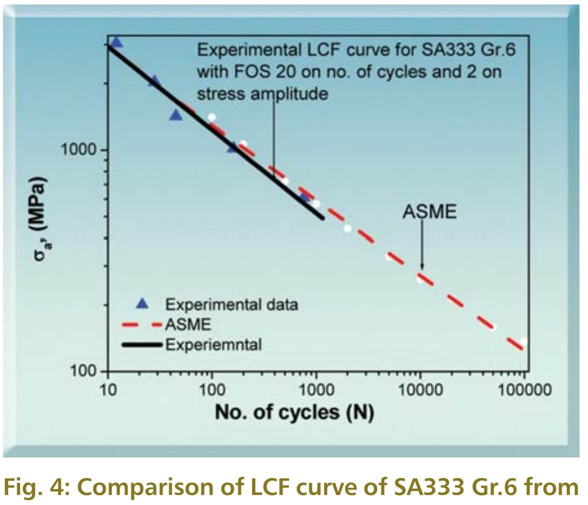

Fig. 4: Comparison of LCF curve of SA333 Gr.6 from experiment and ASME for C-Mn steel

temperature 288°C showing that, the material is susceptible to Dynamic Strain Aging (DSA). Samuel K.G. et al [9] have made a similar observation. LCF curve was also compared with ASME Section II of Boiler and Pressure Vessel code design fatigue curve. In order to do so, a factor 2 on stress and 20 on number of cycles was used, on experimental data points, because ASME design fatigue curve takes into account these factors. The comparison is shown in Fig. 4. It is observed that material fatigue curve compares well with that given by ASME Section II of Boiler and Pressure Vessel code for C-Mn steel.

Fatigue Crack Growth Rate: Specimen Tests Results

The FCGR tests on specimens were conducted to determine the crack growth rate constants. FCGR is modeled using the Paris Law given as: $da / dN = C (\Delta K)^m$, where $\Delta K = \Delta\sigma\sqrt{(\pi a)}F_g$, C and m are FCGR constants, Ds is applied stress, 'a' is crack depth, F_g is geometry factor(depends on the pipe and notch size). As mentioned earlier, several tests were conducted to understand the effect of different parameters such as stress ratio, source of specimens, thickness of specimen etc. The experimentally observed effects of these parameters are discussed in the following paragraphs.

Effect of Stress Ratio and Type of Specimen

The fatigue crack growth rate curves were generated for stress ratios as per the ASTM standard E647 [3] using TPB and CT specimens machined from the same pipe material. The effect of R is shown in Figs. 5 and 6. The comparison of da / dN obtained using CT and TPB is shown in Fig. 6. These specimens were machined from 400 mm outer diameter pipe. Figures indicate that, for a given ΔK, da / dN increases with increase in stress ratio. This effect is relatively more significant at lower R-values. This variation is mainly because of the crack closure effect, which gets reduced as stress ratio increases. It is also observed that da / dN versus ΔK behaviour is nearly the same in CT and TPB specimen tests.

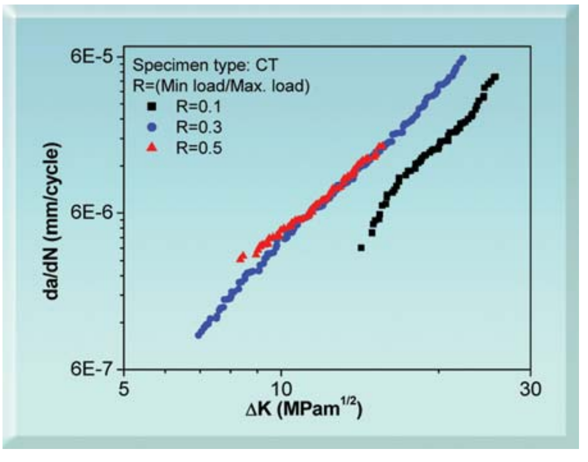

Fig. 5: Comparison of FCGR curves at different stress ratios, obtained using CT specimens

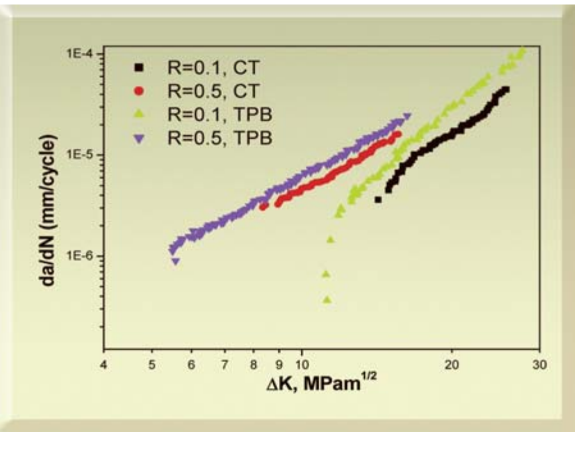

Fig. 6: Comparison of da/dN for CT and TPB specimens

Effect of Thickness and Product Form

TPB specimens were machined from all sizes of pipe of diameter such as 219 mm, 324 mm and 406 mm. The specimens from different pipe sizes differed with respect to thickness. The aim of this study was to see the effect of thickness of specimen on FCGR. The results are shown in Fig. 7. It was found that there is no significant difference in the FCGR property.

Specimens machined from pipes and elbows also exhibit the same FCGR behaviour, as shown in Fig. 8. This indicates that manufacturing process of the piping components, does not affect FCGR curve significantly, for this grade of steel.

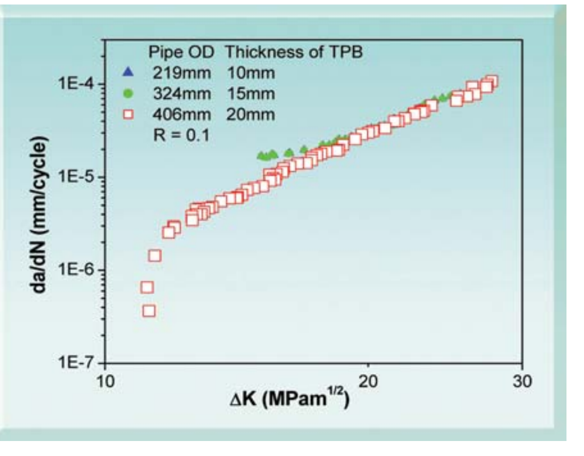

Fig. 7: Comparison of FCGR curves for specimens of different thickness machined from various sizes of pipes

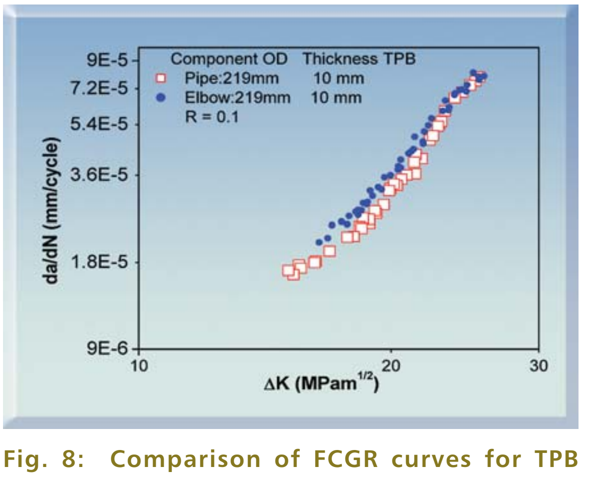

Fig. 8: Comparison of FCGR curves for TPB specimens machined from pipe and elbow

Effect of Notch Orientation with Respect to Pipe Extrusion Axis

CT specimens machined from the 400 mm outer diameter pipe were tested in two orientations, namely LC and CL. In CL orientation, the notch is in longitudinal direction with respect to the pipe, whereas in LC orientation it is in circumferential direction. The test results in Fig. 9 show, that there is no significant difference in FCGR behaviour with respect to orientation of the notch and with respect to pipe axis.

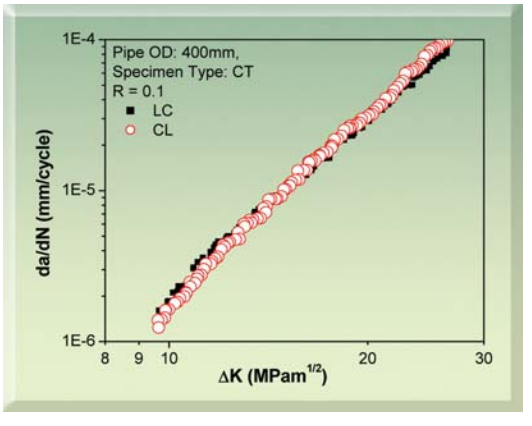

Fig. 9: Comparison of FCGR curves for specimens notch in different orientations with respect to pipe axis

Effect of Base and Welds

TPB specimens were prepared from different sizes of pipes and pipe welds and tests were carried out. The test results for CT specimens from pipe (base) and pipe weld of 406 outer diameters are compared and shown in Fig. 10. FCGR curves obtained for TPB specimens from pipe welds of outer diameters 219, 324 and 406 mm are also compared and shown in Fig. 11. Comparison of FCGR curves for base and weld obtained using TPB specimens are shown in Fig. 12. Figs. 10 and 12 indicate that there is no significant difference between base and welds of different sizes of pipes.

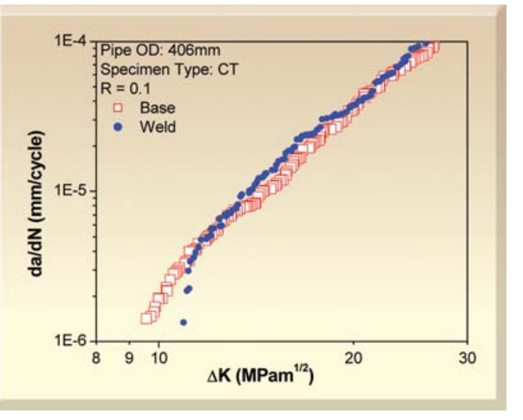

Fig. 10: Comparison of FCGR curves for specimens machined from pipe and pipe weld

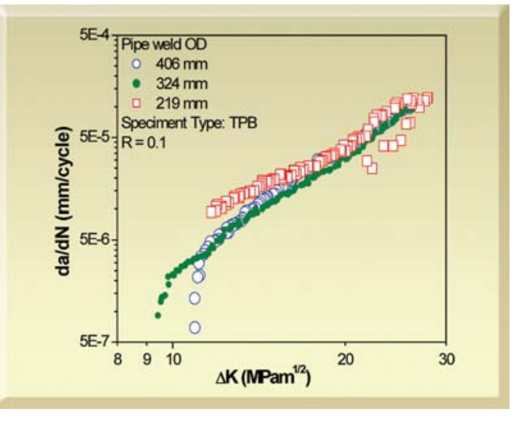

Fig. 11: Comparison of FCGR curves for TPB specimens from different sizes of pipe welds

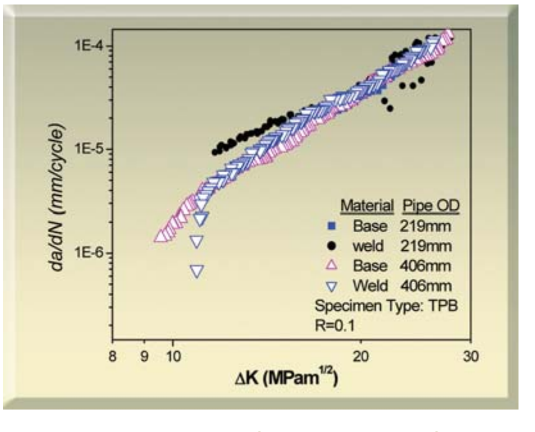

Fig. 12: Comparison of FCGR curves of base and weld using TPB specimen

Summary of the specimen testing

The above results show, that for the present grade of material, the FCGR is not significantly affected by specimen type (CT and TPB), specimen thickness, product form (specimen from elbow and pipe), base and weld metal and notch orientation. The effects of stress ratio are mildly significant at lower R-values.

Component Test Results

The basic aim of carrying out the fatigue tests on components (that is, pipe and elbow), was to compare the fatigue crack growth rate determined using specimens (CT or TPB) and that of pipe which is under more realistic stress field. A brief detail of the fatigue tests on pipes and elbows was described in the preceding section. Milling machining process was used, to machine the blunt notch having a tip radius of approximately 0.1 mm. This value was assumed based on milling cutter tip radius and hence, it is approximate.

The initial cycles of loading produce sharpening of machined blunt notch. Once the crack tip is sharpened, then each loading cycle produces incremental crack growth. The initiation of crack was detected using instrument based on Alternating Potential Current Difference (ACPD) technique. The instrument used, had a detection threshold of 0.1 mm. This in turn implies that, crack initiation can only be detected after a crack growth of 0.1 mm. In few cases crack initiation could only be detected after a crack growth of 0.5 mm. The experimental findings and related number of cycles to crack initiation, fatigue crack growth and their analytical modeling are discussed in the following sections.

Analytical Estimation for crack initiation

In order to predict the number of cycles to crack initiation, a model was used, in which the elastic-plastic strain range is estimated, based on K-fields (where K is linear elastic crack driving force parameter) combined with Neuber's Rule. The crack tip triaxiality was accounted for, by using a correction term based on A-16, appendix of RCC-MR code [12]. These calculations are based on cyclic stress strain curve of this material. Briefly the model can be described as follows:

It is assumed, that the state of stress is plane 2D type. For the notch having a tip radius ρ and the remote stress range $\Delta\sigma^0$, the approximate value of maximum pseudo elastic stress range $\Delta\sigma^{pe}$, at distance d (known as characteristic distance), from the notch tip can be evaluated by the Creager formula (Creager et al, 1967) [10].

$$\Delta\sigma^{pe} = [\Delta K / \sqrt{(2\pi\, r)}] \times (1.0 + \rho/2r) \qquad (3)$$

where, $r = d + \rho/2$ ($\rho = 100\ \mu m$ based on cutter radius, $d = 70\ \mu m$).

ΔK (stress intensity factor range) $= \Delta\sigma^0 \sqrt{(\pi a)} \times F_G$;

For Pipe

$\Delta K = (\Delta\sigma_m . M_m + \Delta\sigma_b . M_b)\sqrt{\pi a} \times F_G$; For Elbow

$\Delta\sigma_m$ is Membrane stress range, M_m is Correction factor for membrane stress $\Delta\sigma_b$ is Bending stress, M_b is Correction factor for bending stress, a = depth of the notch, F_G = Geometry factor (A16, 1995) (depends on the type of notch, shape of the component and type of load).

After evaluation of $\Delta\sigma^{pe}$, the corresponding pseudo elastic strain range has been evaluated by equation (4), which approximately takes into account the state of tri-axial stress on the pseudo plastic strain range

$$\Delta\varepsilon^{pe} = (\Delta\sigma^{pe}/E) \times [\,2(1 + \mu)/3] \qquad (4)$$

where μ is the Poisson's ratio = 0.3

Once the elastic plastic strain range is known then the number of cycles to crack initiation is determined from the LCF curve. This procedure is similar to that recommended by French A-16, Appendix of RCC-MR code. Predicted number of cycles required for crack initiation are given in Table 6 for the pipes and elbows for which crack initiation could be detected at 0.1 mm of crack growth.

The comparison of experimental and analytical crack initiation results, given in Table 2, show that agreement is reasonable for many cases for this appropriate model. Differences in the experimental and analytical results may be due to various assumptions made in the model of fatigue crack initiation. Initiation of the crack is strongly dependent on the material condition, state of stress ahead of the crack tip and characteristic distance (d) ahead of notch tip. In reality, characteristic distance varies with grain size and inclusion content of the material and hence it is difficult to determine an exact value. The state of stress is assumed to be plane 2D and the triaxiality effect is accounted for approximately in the present model.

Fatigue Crack Growth in Component: Test Results

The fatigue crack growth tests on pipes and elbows were conducted, to determine the crack growth rate constants and demonstrate the Level II requirement of LBB assessment. As mentioned earlier, several tests were conducted to understand the effect of different variables such as stress ratio, notch orientation, pipe size, pipe and pipe weld. The experimentally observed effects of these variables are discussed in the following sections.

Comparison of FCGR between pipes and specimen (CT or TPB)

FCGR curves were determined for pipes, from the crack length versus number of cycles record,

Table 2: Comparison of experimental and analytical results for crack initiation

Test no.	Component	Stress ratio	Experimental (for crack to grow by 0.1 mm)	Analytical
PBSC8-1	Pipe	0.1	53,000	89,646
PBSC8-2	Pipe	0.5	320,000	344,275
PBSC8-3	Pipe	0.5	235,000	250,329
PBSC8-4	Pipe	0.1	8,000	6,000
PBSC8-5	Pipe	0.5	45,000	35,835
PBSC8-6	Pipe	0.1	3,000	4,098
PBSC12-1	Pipe	0.1	2500	1550
PBSC16-1	Pipe	0.1	500	278
PBSC16-4	Pipe	0.1	400	270
EWC8-2	Elbow	0.1	249000	240180
ESCC8-3	Elbow	0.1	2000	2556
ESCI8-4	Elbow	0.1	8000	13629

obtained during the tests. Stress intensity factor range was evaluated based on the stress range, instantaneous crack length and the geometry factor [13]. FCGR curves determined for 219 mm, 324 mm and 406 mm outer diameter pipes are shown in Figs. 13 to 16. The comparison of crack growth rate curves of pipes with TPB specimens and the ASME curve [4] are shown in Figs. 13, 15 and 16. The comparison of the crack growth curve indicates that for all ΔK, the crack growth rate given by ASME is higher. It can be inferred that use of the crack growth rate given in ASME will give a conservative prediction.

From the component test results it can be concluded, that the FCGR curve for the pipes and TPB specimens, are not significantly different. Experimental FCGR curve for pipes lies on the lower side of ASME Section XI curve. This observation is consistent with the specimen test results, too. Prediction of fatigue life based on Paris constants given in ASME, will be conservative.

Effect of stress ratio on FCGR in pipes

In the previous section, effect of stress ratio on FCGR has been brought out based on the results of the tests on CT or TPB specimen. Investigations on the stress ratio effect on FCGR have

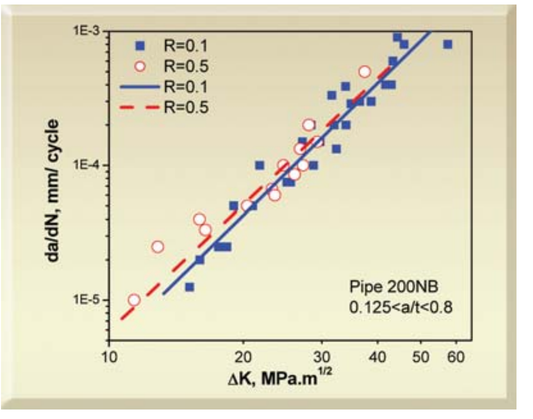

Fig. 14: Comparison of FCGR curves for pipe for different stress ratios

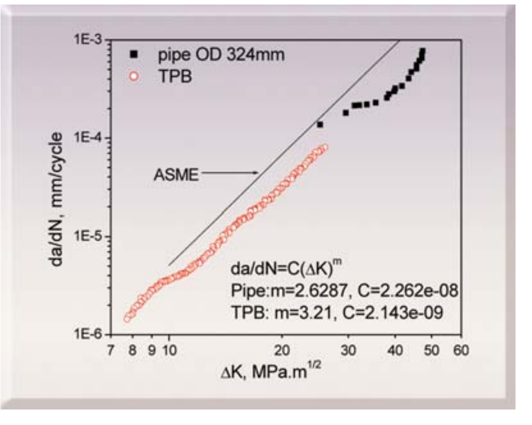

Fig. 15: Comparison of FCGR curves for pipe of 300mm outer diameter and TPB specimen

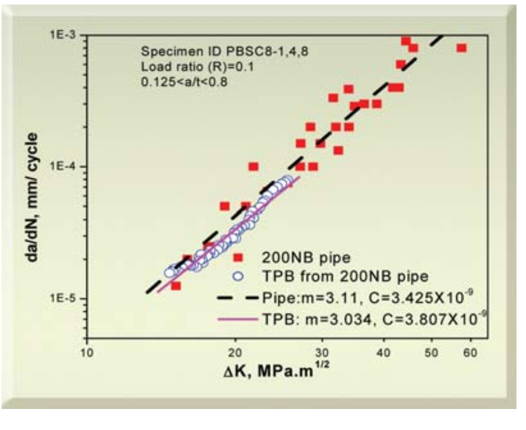

Fig. 13: Comparison of FCGR curves for pipe and TPB specimen

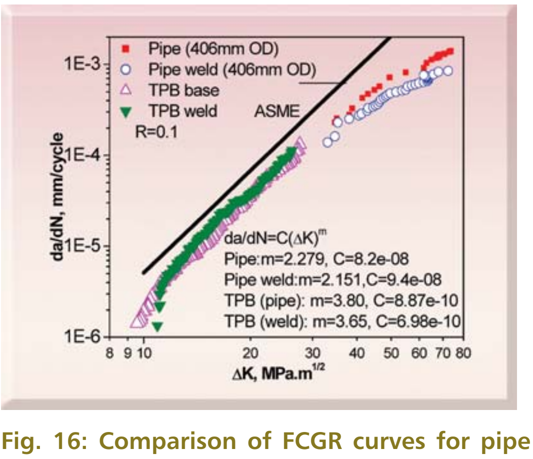

Fig. 16: Comparison of FCGR curves for pipe (406 mm) outer diameter and TPB for base and weld)

been also carried out for pipes and is shown in Fig. 14. This figure indicates that FCGR is mildly affected by stress ratio in Paris region, which is consistent with the observation of specimen test results.

Aspect ratio evaluation with crack growth in pipe

During the pipe test, crack length (circumferential direction) and crack depth (thickness direction) were measured at different loading cycles. Based on this data, variation of crack aspect ratio (2C/a) with crack growth in thickness direction is shown in Fig. 17 for 300 NB and 400 NB pipes. It is observed that aspect ratio decreases and becomes constant in the range of 4 to 5 at the time of through wall. Variation in 2C/a versus a/t behaviour, as shown in Fig. 17, clearly highlights, that crack grows more rapidly in the depth direction than in surface direction. Such behavior is very important from the point of view of Level 2 LBB requirements.

Crack depths were measured along the crack length using ACPD instrument for all the cases. Typical crack shapes as measured using ACPD and on the fracture surface are shown in Figs. 18 and 19 respectively.

Analytical Estimation for FCGR in component

In order to predict the number of cycles required for a crack to grow through thickness after crack initiation, analytical calculations were carried out based on the Paris law. In this analysis FCGR constants obtained from the TPB specimen were used. The details of the analysis can be seen in the paper by Singh et al [11].

Experimental and analytical results (shown in Figs. 21-22 for pipes and Fig. 23 for elbow) for crack growth in the thickness direction have been observed to be in good agreement for the pipes till a/t= 0.8. Fig. 3 shows the crack growth for the crown notched elbow where closing bending moment is applied. The closing bending moment

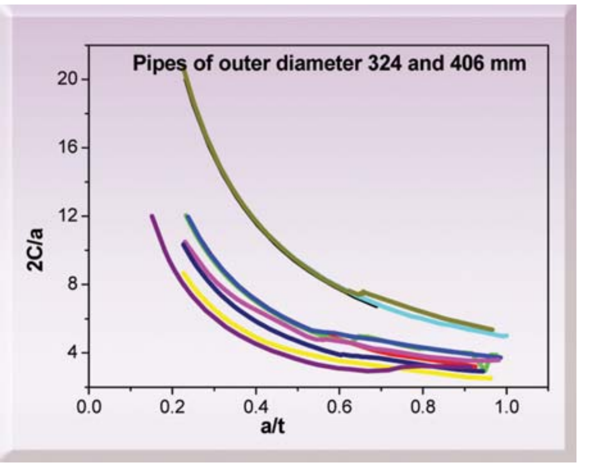

Fig. 17: Variation in aspect ratio with crack growth in thickness direction

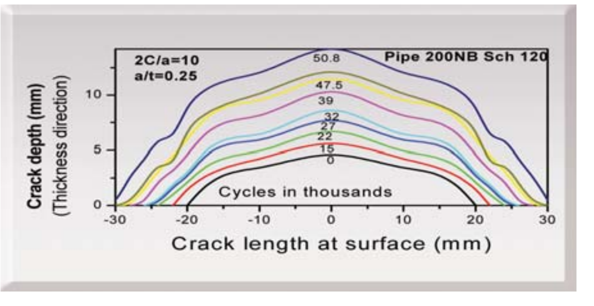

Fig. 18: Crack shape measured using ACPD based instrument

Fig. 19: Typical fatigue fracture surface of pipe (1x1)

introduces stress gradient across the thickness (maximum at outer surface and minimum at the inner surface). This stress pattern leads to

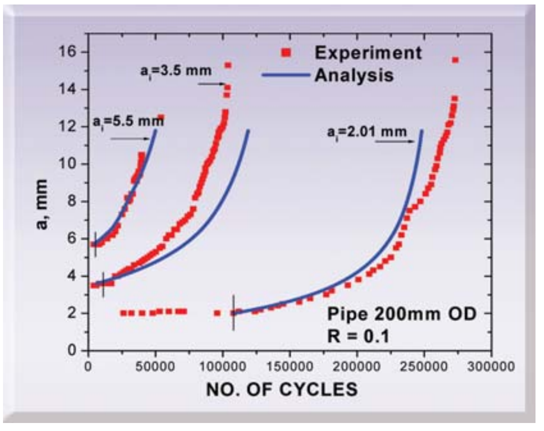

Fig. 20: Maximum crack depth vs number of cycles for different initial crack depths (a_i) and R=0.1

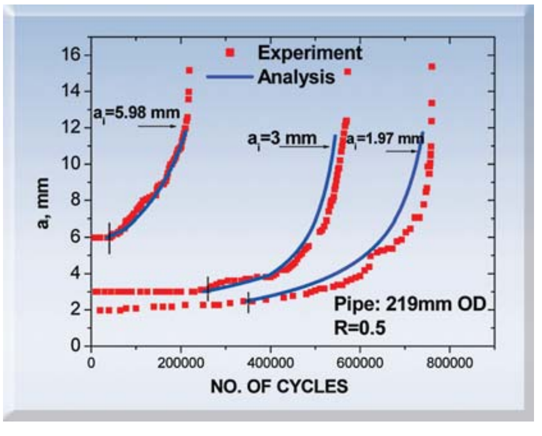

Fig. 21: Maximum crack depth vs number of cycles for different initial crack depth (a_i) and R=0.5

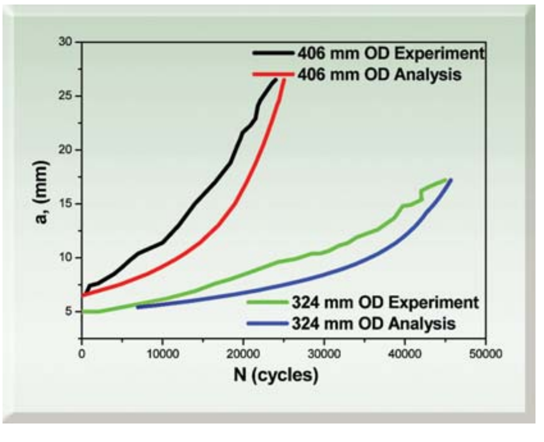

Fig. 22: Comparison of experimental and analytical crack growth for pipes of different outer diameters

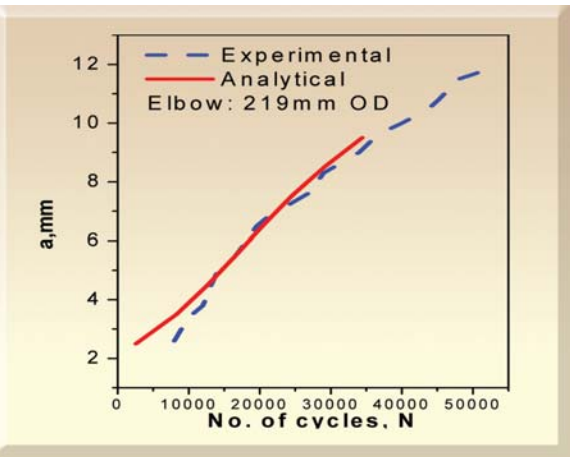

Fig. 23: Comparison of experimental and analytical crack growth for crown crack elbow

decreasing stress intensity factor range from outer to the inner surface. Hence, the crack growth pattern decreases with crack growth in thickness direction. The overall comparison of analytical and experimental observation proves, that the fatigue crack growth model, as discussed in the present paper, yields satisfactory results.

Conclusions

The study describes the fatigue behaviour of carbon steel material and piping components used in Indian PHWRs. It also compares the fatigue behaviour of pipe welds with base material. The results of the study can be summarized as follows

1. Low cycle fatigue properties are higher (better) at room temperature as compared to 288° C for low strain range, whereas at higher strain range, properties are almost identical. Fatigue strength (life) curve of SA333 Gr.6 compares well with that given by ASME Section II of Boiler and Pressure Vessel code for C-Mn steel.
2. FCGR does not depend on notch orientation, pipe size, manufacturing process. FCGR in case of base and weld are also the same. There is a mild dependence on stress ratio at lower values of R.

3. FCGR Paris law constants obtained for the pipe and standard specimen, prepared from the tested pipe, are approximately the same for all the pipes. Slope of Paris curve, that is, m, is marginally higher for TPB as compared to that of pipe.
4. Number of cycles to crack initiation can be predicted relatively well by a model based on evaluation of local stress based on fracture mechanics approach.
5. The use of the fatigue crack growth curve given in ASME Section XI will predict conservative results.
6. Experimental results also confirm that significant margin is available against Level 2 LBB requirements. The number of cycles required to produce through wall penetration is considerably higher than that anticipated in Indian PHWRs.
7. The crack growth in depth (thickness) direction is significantly more rapid than in length (circumferential) direction. This is desirable for application of LBB.

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INTERNATIONAL WORKSHOP ON HYDRIDE EMBRITTLEMENT OF METALS- HEM08

The Materials Group, BARC organized an international workshop on 'Hydrogen Embrittlement of Metals - HEM08' on February 18-20, 2008 at Multi-purpose Hall, Training School Hostel, Anushaktinagar, Mumbai. Dr. A. K. Suri, Director, Materials Group, BARC delivered the welcome address and described the entire spectrum of Hydride Embrittlement ofmetals and its relevance to our departmental programmes. Dr. S. Banerjee, Director, BARC delivered a thought provoking inaugural talk entitled "Can formation of γ - and δ - hydrides be described as bainitic transformation ?". Dr. R. N. Singh, Convener HEM08 proposed the vote of thanks.

Hydrogen embrittlement (HE) of metals is a type of material degradation, caused by dissolved hydrogen, precipitation of hydrogen, hydrogen bearing gaseous phases or hydride precipitates. In case of hydride forming materials, embrittlement is caused by the presence of brittle hydride phase whereas in case of steels, it is caused by the dissolved hydrogen, which is reported to reduce the decohesion energy. HE is manifested in terms of reduction in tensile ductility, impact and fracture toughness, provided, hydrogen (either as hydride in hydride forming metals or in solution for other metals) is present in excess of critical hydrogen concentration.

Several approaches such as thermodynamics, diffusion, phase transformation, microstructure evolution, structure-property correlation, material testing, non-destructive testing, solid mechanics or fracture mechanics, phase field simulation and finite element methods are being used, to analyze and understand these phenomena. The objective is to identify embrittlement parameters which can be used for safety assessment, informed risk management, residual life estimation and life extension of engineering components.

About 200 participants of HEM08 comprised of experimentalists, theoreticians and engineers. HEM08 was structured in one plenary and nine theme based sessions. In all there were four plenary lectures, thirty-two invited talks and nineteen contributed oral presentations. Selected peer reviewed manuscripts were published in the proceedings of HEM08.

HEM 08 also provided an opportunity to the participants from various organizations such as Bhabha Atomic Research Centre, Nuclear Power Corporation of India Limited, Nuclear Fuel Complex, Indira Gandhi Centre for Atomic Research, National Metallurgical Laboratory, Oil and Natural Gas Corp., Mico Bosch, Malmo University (Sweden), MPP Consulting (Canada), Korean Atomic Energy Research Institute (South Korea), Moscow Engineering Physics Institute (Russia), St. Petersburg University (Russia) to network with each other.

The European Commission and constituent units of the Department of Atomic Energy such as Board of Research in Nuclear Sciences, Mumbai, Bhabha Atomic Research Centre, Mumbai, Atomic Energy Regulatory Board, Mumbai and Nuclear Fuel Complex, Hyderabad sponsored HEM08.

DISCUSSION MEET ON ELECTROANALYTICAL TECHNIQUES AND THEIR APPLICATIONS (DM-ELANTE-2008): A REPORT

A Discussion Meet on EleIctroAnalytical Techniques and Their Applications (DM-ELANTE-2008) was organized by the Indian Society for ElectroAnalytical Chemistry (ISEAC) at Tea County, Munnar, Kerala during February 25-28, 2008. The scope of the meet was to familiarize the scientists with the latest developments in the field and to expose them to new developments in electroanalytical techniques and their applications in different areas. The meet was inaugurated on February 25, 2008 by Prof. V. Venugopal, Director, Radiochemistry and Isotope Group, BARC. He talked about the contributions of Electrochemistry in the nuclear power programme of our country and also formally released the bound volume containing manuscripts of invited talks and contributed papers. He lauded the focused activities of ISEAC in promoting the potential applications of electrochemistry, particularly, analytical applications. Prof. S.K. Aggarwal, President, ISEAC, Chairman, Organizing Committee and Head, Fuel Chemistry Division, BARC welcomed the delegates and briefed them about the activities of ISEAC since its inception in October 2003. Mr. N.Gopinath, Convener, Organizing Committee, from Fuel Chemistry Division, BARC gave a brief summary about the various topics of both fundamental and applied Electrochemistry to be covered during the meet. Dr. (Ms.) Jayshree Kamat, Treasurer, ISEAC proposed a vote of thanks.

About 60 participants including 8 overseas speakers participated in this discussion meet. There were 15 Invited talks, 7 Tutorial lectures, 28 Contributed papers (presented as posters) and 4 Research

Prof. V. Venugopal, Director, RC&I Group, BARC inaugurating the DM-ELANTE-2008. From left: Dr. (Ms.) J.V. Kamat, Treasurer, ISEAC, Prof. S.K. Aggarwal, President, ISEAC, Chairman, DM-ELANTE-2008 & Head, Fuel Chemistry Division, BARC, Mr. N.Gopinath, Secretary, ISEAC and Convener, DM-ELANTE-2008.

Scholars' papers which were presented during the meet. All the contributions were spread over 11 Technical Sessions. Invited speakers from overseas included Prof. Kurt Kalcher (Austria), Prof. John T. Luong (Canada), Prof. Karel Vytras (Czech Republic), Prof. Wolfgang Kaim (Germany), Prof. Su-Moon Park (Korea), Prof. Chee Seng Toh (Singapore), Prof. I. Cukrowski (South Africa) and Prof. Hubert Girault (Switzerland). The speakers from India included Prof. R.N. Goyal (IIT, Roorkee), Dr. Santosh P. Haram (University of Pune), Mr. K.A. Venkatesan (IGCAR, Kalpakkam), Dr. R. Srinivasan (CECRI, Karaikudi) and Dr. H.S. Sharma (FCD, BARC). The scientific topics covered in these invited talks included the role of electrochemistry in bio-sensors, room temperature ionic liquids, study of metal-ligand equillibria, gold nano-particles and nanotubes, carbon paste electrodes, micro-electrodes, spectro electrochemistry and impedance spectroscopy. Besides this, there were tutoriallectures on voltammetric determination of ultra trace heavy metal ions; evaluation of DCP and DPP signals; probing cells, cell behavior, cytotoxicity and drug screening using impedance spectroscopy; recent advances in spectroelectrochemical measurements and electrochemistry at liquid-liquid interfaces.

During the valedictory function, some of the delegates were invited to give their impressions about the discussion meet. These delegates expressed their satisfaction over the high quality of technical discussions and the overall arrangements made during the meet. Merit certificates and cash awards were given to the authors of best poster presentations. Prof. S.K. Aggarwal, Chairman, DM ELANTE -2008, thanked all the delegates from India and overseas, as well as sponsors, for their keen interest during the deliberations. In particular, he thanked BRNS (DAE), CSIR, DRDO and the International Society of Electrochemistry (ISE) for co-sponsoring the meet.

Group photograph of Invited speakers and the organizers.
Front row (From left to right): Prof. Wolfgang Kaim (Germany), Prof. Kurt Kalcher (Austria), Prof. S.K. Aggarwal (Chairman, DM-ELANTE-2008, President ISEAC & Head, Fuel Chemistry Division), Prof. V. Venugopal (Director, RC&I Group, BARC), Prof. R.N. Goyal (IIT,Roorkee), Prof. Su-Moon Park (Korea), Prof. John H.T. Luong (Canada), Mr. N.Gopinath (Convener, DM-ELANTE-2008 & Secretary ISEAC)
Standing Second row (left to right): Dr. H.S. Sharma (BARC), Prof. Karel Vytras (Czech Republic), Prof. Ignacy Cukrowski (South Africa), Dr. Santosh K. Haram (Univ. of Pune), Prof. Hubert Girault (Switzerland)

INAUGURATION OF CLEAN ROOM FACILITY AT CDM, BARC

A Clean Room, of Class-10000, was inaugurated by Dr. S. Banerjee, Director BARC on April 2, 2008 at CDM, BARC. This facility has been specially built to house the ultra precision Co-ordinate Measuring Machine (CMM) and other very accurate optical measuring systems used at CDM, in carrying out dimensional measurements with accuracy of the order of sub micron levels for small lengths up to 350 mm to a few microns for 1500 mm long components. The prerequisite to achieving this measurement capability, needs controlled environment Clean Room facility having (a) Temperature of air very closely controlled and maintained at 20° C, with negligible thermal gradient and (b) Humidity of air controlled within 50% RH. A Class 10,000 Clean Room facility of size 11 metres x 7 metres, with above mentioned operating environmental conditions has been built, by teams from A&CED and Mechanical Projects Section (TSD). It is a modular Clean Room facility built out of pre-fabricated double skin metallic panels, complete with minipleat HEPA filters as terminal filters.

Mr. V. K. Mehra, Director, RPG& ESG, Mr. Manjit Singh, AD, DMAG and Mr. L.M. Gantayet, AD, BTD Group graced the occasion. Among others Mr. R. L. Suthar, Head, CDM; Mr. N. S. Gabhane Head, TSD; Mr. A. K. Singh, Chief Project Engineer, TSD; Mr. M. S. Vijay, Head Electrical Projects, TSD; Mr. S. K. Kaul, Head Mechanical Design, TSD; Mr. A. S. Pandharipande, Enginner-in-Charge Metrology Lab., CDM; Mr. R. K. Gupta, Sr. Engineer, CDM and Heads of Sections / EICs of CDM, along with concerned staff of CDM and TSD were also present, during the inauguration.

Mr. R.L. Suthar, Head, CDM welcomed Director BARC and explained to him the overall specifications / functioning of the Clean Room as well as special features of ultra precision Co-ordinate Measuring Machines and other precision measurement systems housed in the Clean Room as well as the other inspection instruments located just outside the Clean Room. Dr. Banerjee appreciated the setting up of this facility, which is unique to BARC.

Dr. S. Banerjee, Director, BARC inaugurating the Clean Room at CDM

INTERNATIONAL SYMPOSIUM ON NEUTRON SCATTERING 2008

The DAE-BRNS International Symposium on Neutron Scattering 2008 (ISNS 2008) was held in Mumbai, during January 15-18, 2008. The Symposium covered various aspects of neutron scattering research and applications in Physics, Chemistry, Biology and Materials Science. More than 200 participants from 15 countries included several leaders in neutron scattering from advanced laboratories in Australia, Canada, France, Germany, Japan, Russia, Sweden, Switzerland, UK and USA.

Dignitaries including pioneers in neutron scattering activity in India, graced the occasion and participated in the deliberations. Dr. Anil Kakodkar, Chairman, Atomic Energy Commission and Secretary, Department of Atomic Energy, Government of India, inaugurated the Symposium. Dr. Srikumar Banerjee, Director, BARC, presided over the inaugural function and Dr. G. Venkataraman, Former Vice-Chancellor, Sri Sathya Sai University was the Chief Guest. Dr. V.C. Sahni, Director, Physics Group, BARC and Director, Raja Ramanna

At the inauguration from left to right : Dr. S. Banerjee, Director, BARC, Dr. G. Venkataraman Chief Guest, Dr. A. Kakodkar, Chairman, AEC and Secretary, Dept. of Atomic Energy, Dr. V.C. Sahni, Director, Physics Grp. and Director RRCAT, Indore, Dr. S.L. Chaplot, Head, Solid State Physics Divn.

Centre for Advanced Technology, Indore, gave introductory remarks about the Symposium. Dr. J. V. Yakhmi, Associate Director (S), Physics Group, welcomed the participants and Dr. S.L. Chaplot, Head, Solid State Physics Division proposed the vote of thanks.

There were 48 invited talks out of which 40 talks were delivered by delegates from ORNL, ANL, LANL, UCSD, NIST, Chalk River, ISIS, PSI, ILL, LLB, HMI, FRM2, FZJ, FZK, JINR, Vienna, Copenhagen, Warwick, JAEA, J-PARC and ANSTO. The talks covered topics such as new experimental facilities and studies involving diffraction, magnetism, biological Systems, hydrogen and diffusion, dynamics, neutron optics, small-angle scattering, reflectometry and other applications. Present day mega-facilities, upcoming as well as proposed, were presented There were also 90 contributed papers put up as posters. Presentations covered a wide range of topics on neutron scattering.

The Symposium was fully funded by BRNS and was organized in cooperation with IAEA. The talks were delivered in the beautiful auditorium at Nabhakiya Urja Bhavan and the poster session was held at the Training School Hostel cum Guest house at Anushaktinagar, Mumbai.

Researchers from universities and other academic institutions, utilize the National Facility for Neutron Beam Research at BARC regularly. Several research projects have been carried out under the aegis of UGC-DAE-CSR. In addition to this, the Facility has been extensively used by BARC for basic research in Condensed Matter Science. This International Symposium facilitated useful scientific discussions among the national and international researchers and was of immense benefit to the research and development activities at BARC. In particular, informal discussions included possibilities of our participation in international collaborations with some of the most advanced research centres and also in a proposed Asia-Oceania Neutron Scattering Association.

In the concluding session, it was suggested that this International Symposium should be held once in every three years in India.

A group photograph of the participants

ICTP REGIONAL COLLEGE ON MEDICAL PHYSICS - 2007

The ICTP Regional College on Medical Physics-2007 was organized by the Radiological Physics & Advisory Division, Health Safety & Environment Group, BARC at CT&CRS Building, Anushaktinagar, Mumbai during November 12 - 23, 2007. The objective of this international college was to update and refresh the knowledge and skill of qualified medical physicists, who can make direct contributions to the improvement of healthcare in their institutions, through optimized medical imaging diagnosis and radiation therapy procedures. The Abdus Salam International Centre for Theoretical Physics (ICTP) conducts College on Medical Physics (CMP) every alternate year at its campus in Trieste, Italy since 1982, for the benefit of medical physicists from developing countries. This was the first ICTP College on Medical Physics organized outside Italy.

The first week of the college was devoted to the Physics and Technology of Medical Imaging and the second week to the Physics and Technology of Radiation Therapy. Prof. Perry Sprawls, Emeritus Professor, Emory University, USA and Dr. S. D. Sharma, Scientific Officer (E), RP&AD, BARC, Mumbai were academic directors of this college. The principal learning activity was the classroom presentations and discussions. Printed handouts, visuals (Power Point) on CD ROMs and video recordings of all the presentations were also made available to the participants. These resources provided significant enrichment to educational

At the inauguration: On the dais (from left to right): Prof. Perry Sprawls, USA, Mr. S. Kannan, Head, RP&AD, Dr. (Ms) K.A. Dinshaw, Director, TMC and Mr. H.S. Kushwaha, Director, HS&EG, BARC

programmes throughout India and the participating countries in addition to contributing to the learning opportunities provided to the participants.

Total registered participants in the college were 67 including 16 from abroad (Bangladesh, China, Indonesia, Iran, Nepal, Philippines, Sri Lanka and Vietnam). Among 51 Indian participants, 36 were from different hospitals of the country while 15 were from different Divisions of BARC, AERB and TMC. Twenty eight faculty members including 5 from USA and 23 from different institutions in India delivered the lectures on topics of their expertise.

The college was sponsored and funded by the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy and the BARC, Mumbai, India. American Association of Physicists in Medicine (AAPM) and the Association of Medical Physicists of India (AMPI) co-sponsored the college. The Board of Research in Nuclear Sciences (BRNS), Mumbai and also leading manufacturer of radiotherapy instruments and equipment, provided financial support for the college. The AMPI, as a co-sponsor, provided significant promotion to the college and participated in the educational needs analysis. The AAPM selected four of its most experienced members and educators to serve on the faculty, two in diagnostic imaging and two in therapy. A special effort was made to enrol all college participants as Developing Country Educational Associates (DCEA) of the AAPM and provide them with instructions on using the Virtual Library and its extensive educational resources. This gives the college participants access to most of the current continuing education material available to AAPM members at the AAPM Annual Meetings, Summer Schools and other educational programmes. This is completely funded by the AAPM and is at no cost to the college participants. Sprawls Education Foundation (SEF) provided printed textbooks and digital media for classroom presentations to all participants.Additional orientation was provided on the effective use of web-based resources. As per feedback received from the participants showed, that they benefited immensely in terms of quality and quantity of information, provided during the college.

Faculty and participants of ICTP Regional College on Medical Physics-2007

भा.प.अ. केंद्र के वैज्ञानिकों को सम्मान
BARC SCIENTISTS HONOURED

श्री यू. पी. कुलकर्णी, श्री के. तिरुमलेश एवं श्री के. शिवन्ना, आइसोटोप अनुप्रयोग प्रभाग, भाभा परमाणु अनुसंधान, प्रशिक्षण केंद्र, अणुशक्तिनगर मुंबई, को जनवरी 27- 31, 2008 के दौरान भाभा परमाणु अनुसंधान केंद्र, मुंबई, में आयोजित आइएसएमएएस की 13वीं विचार-गोष्ठी एवं कार्यशाला के अंशदायी शोध सत्र में रिचार्ज एस्टिमेशन यूज़िंग स्टेबल आइसोटोप एन्ड इंजेक्टेड् ट्रेसर्स एट इन्डियन एग्रिकल्चरल रिसर्च इन्स्टिट्यूट फॉर्म, न्यू देहली नामक शोध-पत्र प्रस्तुत करने पर तृतीय स्थान प्राप्त करने हेतु योग्यता प्रमाण-पत्र प्रदान किया गया।

A certificate of merit was awarded to Mr. U.P. Kulkarni, Mr. K. Tirumalesh and Mr. K. Shivanna of the Isotope Applications Divn., for their paper entitled "Recharge Estimation using Stable Isotope and injected Tracers at Indian Agricultural Research Institute farm, New Delhi". This paper was presented at the 13th ISMAS symposium-cum-Workshop on Mass spectrometry, held between Jan. 27-31, 2008 at Mumbai. The paper secured the third place in the Contributory Papers Session.


Mr. U.P. Kulkarni

श्री. यू. पी. कुलकर्णी ने वर्ष 1973 में पूणे विश्वविद्यालय से स्नातकोत्तर प्राप्त किया। तत्पश्चात वर्ष 1974 में भाभा परमाणु अनुसंधान केंद्र के आइसोटोप अनुप्रयोग प्रभाग में सदस्यता प्राप्त की। तबसे आप जलनविज्ञान में स्थिर आइसोटोप एवं रेडियोआइसोटोप की मात्रामिति तथा अनुप्रयोग कार्य में व्यस्त रहे। आप "आइसोटोप इन दि स्टडी ऑफ पोल्यूटंट बिहेवियर इन दि अनसेच्युरेटेड ज़ोन फॉर ग्राउंड वॉटर प्रोटेक्शन" पर आइ एईए/सीआरपी के मुख्य अनुसंधान कर्ता थे। इन्होने प्रभाग के द्वारा आयोजित बाँध रिसाव अध्ययन, दरिया निस्सारण मात्रामिति, तलछट परिवहन अध्ययन, धरातल एवं भूमिगत जल आंतरिक संबंध एवं झील से निकलने वाली जल धारा का अध्ययन जैसे कई जल विज्ञान अनुसंधानों में भाग लिया है।

Mr. U.P. Kulkarni completed his post graduation from Pune University in 1973 and joined the Isotope Applications Division, BARC in 1974. Since then he has been involved in measurement and applications of radioisotopes and stable isotopes in hydrology. He was Chief investigator of IAEA/CRP on "Isotopes in the study of pollutant behavior in the unsaturated zone for groundwater protection". He has participated in a number of hydrological investigations conducted by the division such as dam seepage studies, river discharge measurements, sediment transport studies, surface water groundwater interconnections and effluent dispersion studies.


Mr. K. Tirumalesh

श्री एम.के. तिरूमलेश ने वर्ष 1998 में उस्मानिया विश्वविद्यालय से एम.एससी की डिग्री प्राप्त की। इन्होंने 1999 में भाभा परमाणु अनुसंधान, प्रशिक्षण केंद्र से स्नातकता प्राप्त करके आइसोटोप अनुप्रयोग प्रभाग में अनुसंधान कार्य आरंभ किया। मुख्यत: ये आइसोटोप अनुप्रयोग एवं जल-स्रोत विकास के क्षेत्र में भू-रसायन पर काम कर रहे हैं। आप एक बीआरएनएस परियोजना के मुख्य सहयोगकर्ता हैं तथा आपने विभिन्न आइएईए/सीआरपीएवंआरएसी परियोजनाओं में भी योगदान दिया है। अंतर्राष्ट्रीय पत्रिकाओं एवं विचार - गोष्ठियों में कई प्रकाशन इनके श्रेय में हैं। इनकी रुचि के क्षेत्र में भू-विज्ञान प्रतिरूप, जलीय

माध्यम एवं धातु विशेषज्ञता तथा आयन रंग-विज्ञान के उपयोग से प्राकृतिक जल में विषाक्त आयन की मापन तकनीक का विकास भी शामिल हैं।

Mr. K. Tirumalesh received his M.Sc. degree from Osmania University in 1998. He graduated from BARC Training School in 1999 and started his research career in Isotope Applications Division. He is working mainly on the application of isotopes and geochemistry in the field of water resources development. He is the principal Collaborator for a BRNS project and has also contributed to various IAEA/CRP and RCA projects. He has a number of publications in international journals and symposia / conferences to his credit. Geochemical modeling, metal speciation in aquatic medium and development of techniques for measurement of toxic ions in natural waters using ion chromatography are his topics of interest.

Dr. K. Shivanna

डॉ. के. शिवन्ना, अध्यक्ष, जल संसाधन विकास विभाग, आइसोटोप अनुप्रयोग प्रभाग, भाभा परमाणु अनुसंधान केंद्र, ने गत 28 वर्षों से आइसोटोप जल विज्ञान के क्षेत्र में उत्कृष्ट योगदान दिया है। ये जल संसाधन विकास एवं प्रबंधन हेतु आइसोटोप जल विज्ञान, जल-भूविज्ञान तथा जलरसायन के क्षेत्र में विशेषज्ञ हैं एवं अंतर्राष्ट्रीय आइसोटोप जल विज्ञान में माने हुए हैं। समाज हेतु इनकी मुख्य वैज्ञानिक उपलब्धियों में हिमालय क्षेत्रों में सूखते झरनों का पुन:पूरण होने वाले क्षेत्र , भारतीय पूर्वी एवं पश्चिमी समुद्रतटों पर भूजल से नमक निकालने की प्रक्रिया, भूजल पुन: चार्ज करने के उद्‌गम एवं स्रोत, भूजल को पुन: प्राप्त करने का काल-निर्धारण, भूजल गुणवत्ता का निर्धारण, उद्‌गम एवं स्रोत प्रक्रिया, संखिया (अरसेनिक), फ्लोराइड, नाइट्रेट एवं अन्य जैव तथा अजैव प्रदूशन पदार्थों से छुटकारा , बाँध, जलाशय, सुरंग, नहर रिसाव एवं भूतापीय क्षेत्र आदि में जल संसाधन जैसी सिविल इंजिनीयरिंग समस्याएं भी शामिल हैं।

इन्होंने आइएईए/आरसीए प्रोग्राम के अंतर्गत अफ्रीका जैसे देशों में जल संसाधन विकास के क्षेत्र यूएनडीपी / आइएईए विशेषज्ञ तथा भूतापीय प्रणाली हेतु राष्ट्रीय समन्वयक की हेसियत से काम किया है।

Dr. K. Shivanna, Head, Water Resources Development Section, Isotope Applications Division of BARC, has made outstanding contribution in the field of isotope hydrology for the last 28 years. He is a specialist in the field of isotope hydrology, hydrogeology and hydrochemistry for water resources development and management and is internationally known in the field of isotope hydrology. His major scientific achievements to the society include: investigation of recharge zones of drying springs in Himalayan regions, assessment of groundwater sustainability and groundwater salinization mechanism in east and west coast of India, source and origin of groundwater recharge, dating of groundwater to confirm the renewability, assessment of quality of groundwater, source, origin and mechanism of release of arsenic , fluoride, nitrate and other organic and inorganic pollutants into groundwater, civil engineering problems like dams, reservoirs, tunnels, canal seepage and water resources development in geothermal regions etc.

He served as a UNDP/IAEA regional expert in the field of water resources development in African countries and as national co-coordinator for geothermal systems under IAEA/RCA programme.

Mr. K.K. Verma

श्री के.के. वर्मा, पुन:ईंधन प्रौद्योगिकी प्रभाग, भा.प.अ. केंद्र को “लोकोमोटिव” श्रेणी के अंतर्गत “विकलांग व्यक्तियों के सशक्तीकरण हेतु उत्कृष्ट कर्मचारी के रूप में राष्ट्रीय पुरस्कार 2007" प्रदान किया गया है। उन्हें यह पुरस्कार विज्ञान भवन, नई दिल्ली में दिनांक 3 दिसंबर,

2007 को आयोजित समारोह में भारत की माननीय राष्ट्रपति श्रीमती प्रतिभा पाटिल द्वारा प्रदान किया गया। यह पुरस्कार भारत सरकार के सामाजिक न्याय एवं सशक्तीकरण मंत्रालय द्वारा स्थापित किया गया है।

श्री वर्मा वैज्ञानिक सहायक के रूप में भा.प.अ. केंद्र में कार्यरत हुए। वे पीएचडब्ल्यूआर, पीएफबीआर एवं एएचडब्ल्यूआर हेतु ईंधन हस्तन प्रणाली के डिजाइन एवं विकास से संबंधित गतिविधियों से जुड़े हैं। उन्होंने अपने ही प्रयासों से सीमित साधनों की सहायता से पीएफबीआर इन-हाउस हेतु एक अनोखा 1:10 स्केल के आनत ईंधन हस्तांतरण मशीन का वर्किंग ऐक्रिलिक मॉडल बनाया है। उन्होंने ऑन-पावर लो-लीकेज मॉनीटरिंग सिस्टम का विकास किया है, जिसका प्रयोग पीएचडब्ल्यूआर हेतु किया जा सकता है। उन्होंने ईंधन हस्तन हेतु विभिन्न प्रणालियों के विकास में भी महत्वपूर्ण योगदान दिया है।

Mr. K.K.Verma, Refueling Technology Division, BARC has received the "National Award 2007 as the Best Employee, for the empowerment of persons with disabilities" under the category "Locomotive" from the Honorable President of India, Smt. Pratibha Patil, at a function held on 3rd December, 2007 at Vigyan Bhavan, New Delhi. This award was instituted by the Ministry of Social Justice and Empowerment, Govt. of India.

Mr. Verma joined BARC as a Scientific Assistant. Later on, he acquired a degree in Mechanical Engineering. He is involved in the design and development activities related to fuel handling system for PHWR, PFBR and AHWR. He has made a unique 1:10 scale working acrylic model of Inclined Fuel Transfer Machine for PFBR in-house, with limited resources through his own initiative. He also developed on-power low-leakage monitoring system, which can be used for PHWR. He has made significant contributions in the development of various other systems for fuel handling.

डॉ. संदीप बासु विकिरण चिकित्सा-विज्ञान केंद्र, भाभा परमाणु अनुसंधान केंद्र, को एल्ज़िवियर द्वारा प्रकाशित विश्व की प्रमुख पत्रिकाओं मे से विषेशत: "दि हैड एन्ड न्येक ऑनकोलोजी सेक्शन

Dr. Sandip Basu

ऑफ दि इन्टरनैशनल जरनल ऑफ ऑरल एन्ड मैक्सिलोफेशल सर्जरी" नामक पत्रिका के संपादकीय एवं समीक्षक मंडल की सदस्यता का आमंत्रण दिया गया। प्रस्तुत पत्रिका मौखिक एवं जम्भुतालु के शल्य विज्ञान तथा इसके समर्थक क्षेत्रों में उच्च स्तर के वैज्ञानिक विषेशताओं वाले शोध-पत्रों को ही प्रकाशित करतें हैं।

डॉ. बासु एक नाभिकीय औषध फिजीशियन, नियमित रोग सेवाओं के अतिरिक्त स्नातक प्रशिक्षण एवं अनुसंधान कार्यक्रमों में व्यस्त हैं। इनके श्रेय में कई प्रसिद्ध सूचीबद्ध उच्चस्तरीय पुनरावलोकित राष्ट्रीय एवं अंतर्राष्ट्रीय प्रकाशन हैं। विशेषत: इनकी रुचि के क्षेत्र में थाइराइड संबंधित विकार, रोगी में संघाती एवं सौम्य विकार की चिकित्सा संबंधी पॉज़िट्रॉन निस्सारण टॉमोग्राफी का अनुप्रयोग तथा केंसर रोगियों की रेडियो एक्टिव न्यूक्लाइड चिकित्सा है। डॉ. बासु इस प्रतिष्ठापूर्ण पत्रिका के समीक्षक तथा संपादक मंडल में एक ही भारतीय चिकित्सक वैज्ञानिक हैं।

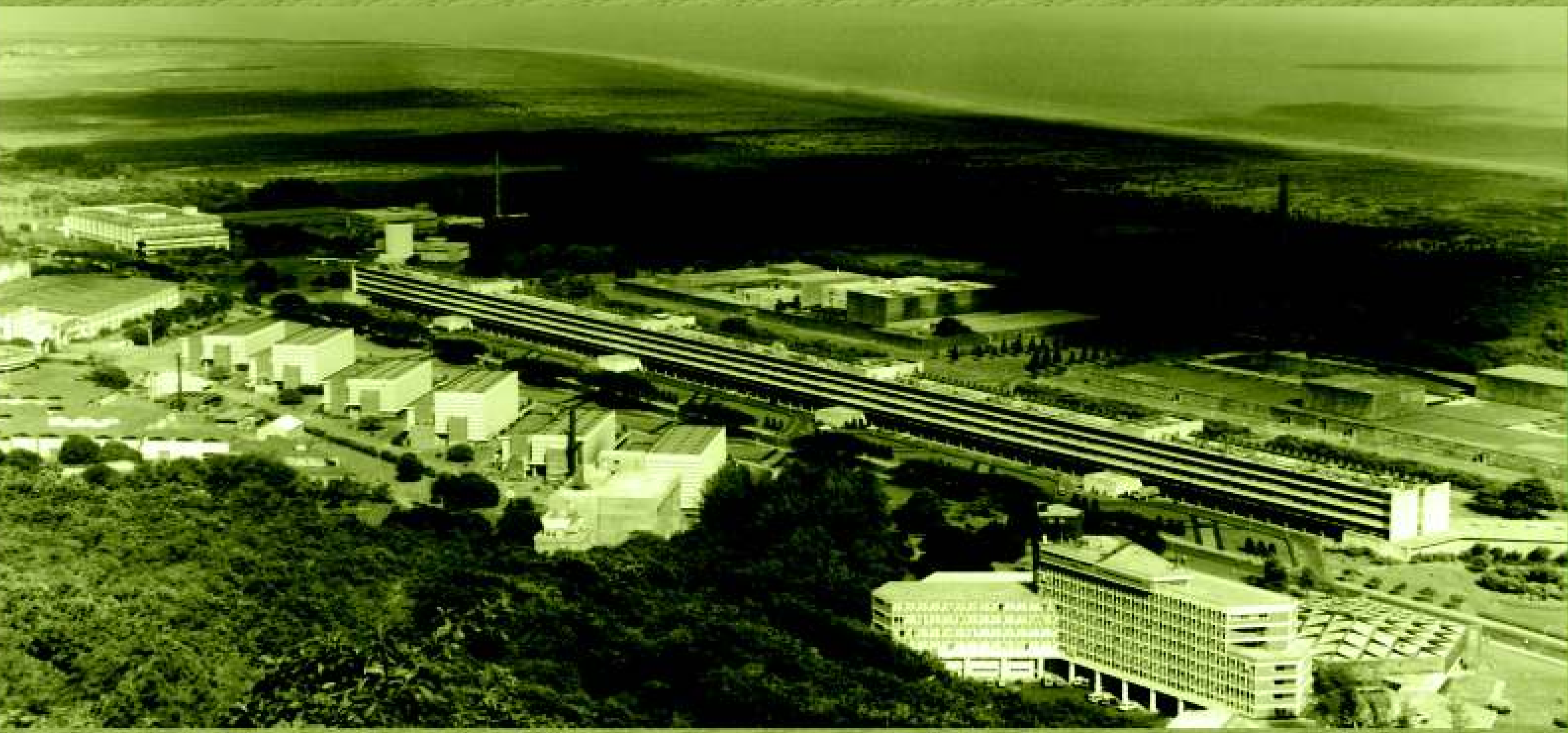
Dr. Sandip Basu of Radiation Medicine Centre, BARC, has joined on invitation, the Editorial Board and the Reviewer Board of the Head and Neck Oncology Section of the *International Journal of Oral & Maxillofacial Surgery,* one of the leading journals in the world in this speciality, published by Elsevier. The Journal publishes papers of very high scientific merit in oral and maxillofacial surgery and supporting fields.

Dr. Basu is a Nuclear Medicine Physician actively involved in research and the postgraduate training activities of the centre in addition to routine patient services. He has several international publications in high impact factor, peer reviewed indexed journals of repute and presentations in international and national conferences. His special interests include thyroid related disorders, clinical applications of positron emission tomography in patients with malignant and benign disorders and radionuclide therapy of cancer patients with unsealed sources. Dr. Basu is the only medical scientist from India on the editorial and the reviewer boards of this prestigious journal.

Mr. R.K. Bajpai

श्री आर.के.बाजपाइ, पश्चंत्य प्रौद्योगिकी विकास प्रभाग, भाभा परमाणु अनुसंधान केद्र को गत 10वर्षों से एप्लाइड जियोकेमिस्ट्र एन्ड एक्सपलोरेशन ऑफ रेडियोएक्टिव मिनरल्ज़, नैचुरल एवं एनलॉगस ऑफ न्युक्लियर वेस्ट फॉर्मस एन्ड जियोलाजिक्ल रिपोज़िट्री रिलेटिड प्रोसेसिज़ के क्षेत्र उत्कृष्ट योगदान के लिए इन्डियन सोसाइटी ऑफ एप्लाइड जियोकेमिस्टस (आइएसएजी), हैदराबाद के द्वारा डॉ.जी आर उदास गोल्ड मेडल पुरस्कार से सम्मानित किया गया। यह पुरस्कार इन्हें एनई भारत के दूरस्थ इलाकों में यूरेनियम एक्सप्लोरेशन के क्षेत्र में उत्कृष्ट योगदान को मान्यता प्रदान करने हेतु दिया गया, जिसके फलस्वरूप मेघालया में अल्ट्रामफिक कार्बोनेटाइट काम्पलेक्स युक्त नई दुर्लभ भूमि अवयवों का अविष्कार हुआ। भारत में पहली बार इन्होंने ही अपशिष्ट कांच, रेडियोएक्टिव न्यूक्लाइड प्रवासी, एवं अथाह उष्म भूवैज्ञानिक भंडार का विवरण दिया है। इनकी विशेषज्ञता गहरे भूवैज्ञानिक भंडार स्थान का चयन एवं चरित्रांकन एवं सतही रेडियो सक्रिय अपशिष्ट की निपटान सुविधाऐं , इनका स्थायित्व मूल्यांकन, मंद संवेदनशीलता एवं जीआइएस प्रौद्योगिकी, इंजीनियरिंग एवं स्ट्रक्चरल जियोलोजी, हाइड्रोलोजी एवं नेचुरल एनालॉगस ऑफ वेस्ट एन्ड रिपोज़िट्री प्रोसेसिज़ में भी है।

Mr. R.K. Bajpai of Back End Technology Development Division, BARC was awarded the prestigious Dr. GR Udas Gold Medal by the Indian Society of Applied Geochemists (ISAG), Hyderabad for his outstanding contributions in the last ten years in the field of applied geochemistry and exploration of radioactive minerals, natural analogues of nuclear waste forms and geological repository related processes. The medal was conferred on him in recognition of his outstanding contributions in the field of uranium exploration in remote areas of NE India that resulted in discovery of a new Rare Earth Element rich Ultramafic-Mafic-Carbonatite Complex in Meghalaya, significant uranium mineralization in Lesser Himalayas of Arunachal Pradesh, Assam and uranium deposits of Meghalaya. He has also reported, for the first time in India, natural analogues of waste glasses, radionuclide migrations and thermal fields of deep geological repository. His expertise lies in the field of site selection and characterization for deep geological repositories and shallow radioactive waste disposal facilities, their stability assessment, remote sensing and GIS technology, engineering & structural geology, hydrogeology and natural analogues of waste forms and repository processes.



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