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HANDING OVER OF THE TMAC SYSTEM TO TAPS 3 & 4

In the Forthcoming Issue

Study of Quark Gluon Plasma; journey from RHIC to LHC

The study of Quark Gluon Plasma (QGP) is of crucial importance to Physicists around the world, since it would throw some light on the nature of matter, particularly in the context of the Big Bang theory. Powerful colliders can recreate those conditions in the laboratory and help in understanding relativistic heavy ion collisions.

The article gives an insight into two such colliders; the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC); the nature of experiments being carried out by the international scientific community and the discoveries made in the course of these experiments. BARC's participation in both RHIC and LHC programmes has also been covered in this article.

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STRUCTURAL INTEGRITY OF MAIN HEAT TRANSPORT SYSTEM PIPING OF AHWR

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Introduction

The Advanced Heavy Water Reactor (AHWR) is a 920 MWth, 300 MW vertical pressure tube type reactor, with boiling light water as a coolant in a high-pressure Main Heat Transport (MHT) system. The MHT system consists of common circular inlet header, from which 408 inlet feeders branch out to the coolant channel core. The outlets of the coolant channels are connected to the tail pipes carrying steam water mixture from the individual channels to the four steam drums. The steam is separated from steam water mixture in the steam drum and is supplied to the turbine. The condensate is heated in moderator heat exchangers and feed heaters and is returned to the steam drum by the feed pump. For each steam drum, four downcomers are connected to the inlet header.

AHWR is a new reactor being designed with a target life of 100 years. Structural integrity of the MHT system piping is of concern considering the life of 100 years, for which adequate experience and material data are not available. Failure of austenitic stainless steel piping of boiling water reactors, due to Intergranular Stress Corrosion Cracking (IGSCC), has been reported extensively in literature. Prevention of IGSCC in the operating plant and the new plant is of great challenge to design and material engineers. In view of this, it was planned to address all the issues related to structural integrity of the MHT system piping, which are of concern to the long life of the plant. Issues covered under this article are as follows:

1. Selection of material
2. Life limiting material degradation mechanism
3. Optimization of welding process
4. Leak Before Break design criteria

In this article, various factors considered for selection of material for MHT system piping and the technical specification of the chosen material are described. This was extensively discussed among the material experts of the DAE. Life limiting material degradation mechanism such as Low Temperature Sensitization (LTS) that will lead to IGSCC and Low Temperature Embrittlement (LTE) leading to reduction in toughness, were considered. Literature available worldwide and the work carried out till date, under our programme on LTS and LTE is summarized. Welding is one of the widely used joining processes used in the fabrication of piping system and improper selection of welding process and techniques may lead to higher residual stress and deterioration in material properties. The advantages and disadvantages of existing welding process such as Gas Tungsten Arc Welding (GTAW) and Shielded Metal Arc Welding (SMAW) along with newer hot wire GTAW have been brought out. The use of narrow gap welding technique and high deposition rate welding leading to lower residual stress is also demonstrated. This also helps in reducing the material susceptibility to sensitization because of higher cooling rate. Occurrence of IGSCC in austenitic steel piping is a deterrent in demonstration of Leak Before Break (LBB) design criteria. In view of the improved material specification and welding process optimization, the chances of IGSCC will reduce significantly and help in demonstrating the LBB criteria. The defect tolerance of the piping was demonstrated, by carrying out a component test programme showing compliance with LBB criterion.

Selection of material

Material for high energy MHT system components should have good corrosion resistance along with adequate strength and ductility. In addition to this, material should have good fabricability and be easily available. The selection of material is based on the literature survey, discussion with material experts, design codes and standard and the R&D activities carried out under component integrity testing programme. Various factors considered in the selection of material for MHT system piping of AHWR are as follows:

1. Operating conditions and plant life
2. Material properties such as mechanical, metallurgical, irradiation and corrosion resistance.
3. Availability of the material and data for design
4. Ease of fabrication
5. International experience
6. Cost.

Process fluid (coolant) in the MHT system is two-phase steam water mixture and the chemistry of the fluid would be similar to that of typical boiling water reactor. The operating temperature is 288°C.

Austenitic stainless steel is the choice for this application because of its ductility, good weldability, excellent corrosion and erosion resistance properties, adequate strength availability of material data and above all vast experience in the use of this material in boiling water reactors. The experience indicates that Boiling Water Reactor (BWR) piping systems fabricated from AISI type 304 and 316 austenitic stainless steels, have been susceptible to intergranular stress corrosion cracking in the heat affected zone of the pipe girth welds [2]. Extensive testing in BWR environment has demonstrated that reduction in carbon content in austenitic stainless steel reduces susceptibility to IGSCC. This is in conformity with plant performance, in which higher carbon material (more than 0.04%) has cracked in service [3].

In order to provide sufficient margin for the resistance to sensitization of material for Advanced Boiling Water Reactor (ABWR), the maximum carbon content will be specified as 0.02%. For major reactor structures, preferred material is SS316L where lower allowable strength is acceptable. To compensate for lower carbon level, strength is maintained by adding nitrogen up to a maximum of 0.12 % [3].

Austenitic stainless steels of several grades such as SS 304, 316, 304L, 316L, 304LN, 316LN, 321, 347 and their equivalents were considered for choice of the material. SS 304 and 316 are susceptible to sensitization and lead to weld decay. Stabilized austenitic stainless steel such as SS 321 and 347 are less susceptible to sensitization, but may be prone to knife line attack and hot cracking during welding.

Although all the low carbon grades of austenitic stainless steels viz. SS 304L, 316 L, 304LN and 316LN will satisfy the general structural integrity concerns such as fatigue, fracture, general corrosion and erosion; it was recognized that in view of the proposed design life of 100 years for AHWR, aspects such as LTS and LTE will influence the material choice. Resistance to LTS is comparable for SS 304LN and 316LN whereas, resistance to LTE is superior in case of SS 304LN. This is because the kinetics of LTE is faster in the presence of Molybdenum. Since SS 316LN contains Molybdenum, this implies that SS 316LN will embrittle faster than SS 304LN. Therefore, SS 304LN is the choice of material.

The chemical composition of the SS 304LN material for MHT system piping of AHWR was finalized and is given in Table 1 along with corresponding ASME specification SA 312 Type 304LN [3].

to a decrease in cracking up to 0.16% [5]. Cr and Ni limits were modified considering the beneficial effect on LTS behaviour (SS 304 with carbon towards the lower limit, Cr towards higher limit and Ni towards lower limit shows better properties compared to SS 304L with carbon towards the higher limit, Cr towards lower limit and Ni towards higher limit). Phosphorous,

Table 1: Chemical composition (product analysis) in weight %

Element	ASME SA 312 Type 304LN (weight %)	Proposed (Weight %)
C	0.03 max	0.024 max
Cr	18-20	18.5-20
Ni	8-12	8.5-10
Mo	-	0.5 max
N	0.1-0.16	0.06-0.12
Mn	2.0 (max)	1.6-2.0
Si	1.0 (max)	0.5 max
P	0.045 (max)	0.025 max
S	0.03 (max)	0.005 max
Ti	-	0.05 max
Nb	-	0.05 max
O	-	100 ppm max
Cu	-	1.0 max
Co	-	0.5 max

The chemical composition ranges for various elements have been narrowed down to reduce the scatter in material properties. The upper limit of carbon has been reduced to ensure that sensitization during welding will not occur. Lower limit on nitrogen content has been specified for compensating strength due to reduction in carbon. Optimizing corrosion resistance property and weldability considerations decided the upper limit on nitrogen content. Nitrogen addition also enhances resistance to precipitation of certain undesirable phases in austenitic stainless steel. It has a refining effect on the solidification structure, leading

Sulphur and Silicon are treated as impurities and lead to formation of various types of inclusions. P and S also have adverse effect on weldability of the material [4]. Considering the adverse effect of Titanium, Niobium and Copper on weldability, maximum limit has been specified, althoughno such limits exist in ASME specification.The maximum limit on Oxygen has beenspecified, which will lead to reduction in oxide inclusions and increase in corrosion resistance although there are no such limits in ASTM specifications.

In addition to the chemical composition, limits were fixed for inclusion content (less than 6 as per ASTM E45), grain size (more than ASTM No.4), hardness (max 180 VHN) and IGSCC tests (degree of sensitization should not be more than 25% in ASTM A262 Practice A and crack after bending should not be more than 25 micron in ASTM Practice E).

Life Limiting Material Degradation Mechanisms

Identified material degradation mechanism such as LTS and LTE studies were planned to carry out on the base and weld material of the SS 304LN grade. The data available and the work carried out under our program is described below:

Low Temperature Sensitization

When austenitic stainless steels are heated or slowly cooled in the temperature range of 500 to 850°C, Cr rich $M_{23}C_6$ carbides precipitate along grain boundaries leading to chromium depletion in the adjacent regions. This phenomenon is known as *sensitization*. When a stressed and sensitized material is exposed to corrosive media, it undergoes InterGranular Stress Corrosion Cracking (IGSCC). It has also been observed, that carbides nucleated by short exposures in the critical temperature range without a detrimental degree of chromium depletion, can grow during service well below 500°C causing a severe degree of chromium depletion. This phenomenon is known as *Low Temperature Sensitization (LTS)*.

Extensive research on LTS in stainless steel suggests SS 304LN and 316LN as alternative materials to combat LTS likely to be encountered in service. This is because, the time required for the onset of sensitization in stainless steel with low carbon and extra nitrogen is quite high and critical cooling rate below which sensitization takes place is quite low. When carbon is low (<0.03%), very long ageing time at high temperature is required for the nucleation of chromium rich carbide precipitation in sufficient quantities, which may lead to LTS. When nitrogen is also present, the diffusion coefficient of chromium is low and chromium carbide precipitation kinetics becomes sluggish [6].

Low Temperature Sensitization (LTS) studies were carried out to confirm that austenitic stainless steel components (base and weld materials of SS 304LN) will not have LTS problem during service of the plant. These studies were performed on materials subjected to accelerated ageing by simulating time and temperature in such a way, that the kinetics processes remains unaffected. The ageing durations of 1300 and 8000 hours at temperatures 450°C and 400°C were worked out by considering the activation energy of carbide precipitation ~ 150 kJ/mol. Material is also being subjected to thermal ageing at temperature of 350°C for 50000 hours

Table 2: Results of oxalic acid etching and DOS for ageing at 400°C

Aging time(Hrs) at 400°C	304LN-P1 (168 mm OD)		304LN-P2 (324 mm OD)	
	Etch structure	%DOS Weld HAZ	Etch structure	% DOS Weld HAZ
Virgin	Step	0.009 (Base)	Step	0.0054 (Base)
600 Hrs	Step	0.3104	Step	0.212
3000 Hrs	Step	1.1596	Step	0.368
5000 Hrs	Step	2.17	Dual	0.32
8000 Hrs	Step	1.01	Dual	0.4386

Table 3: Results of oxalic acid etching and DOS for ageing at 450°C

Aging Time(Hrs) at 400°C	304LN-P1 (168 mm OD)		304LN-P2 (324 mm OD)	
	Etch structure	%DOS Weld HAZ	Etch structure	% DOS Weld HAZ
Virgin	Step	0.009 (Base)	Step	0.0054 (Base)
125 Hrs	Step	0.243	Dual	0.105
500 Hrs	Step	1.00	Dual	0.165
800 Hrs	Step	1.49	Dual	0.289
1300 Hrs	Step	1.504	Dual	0.504

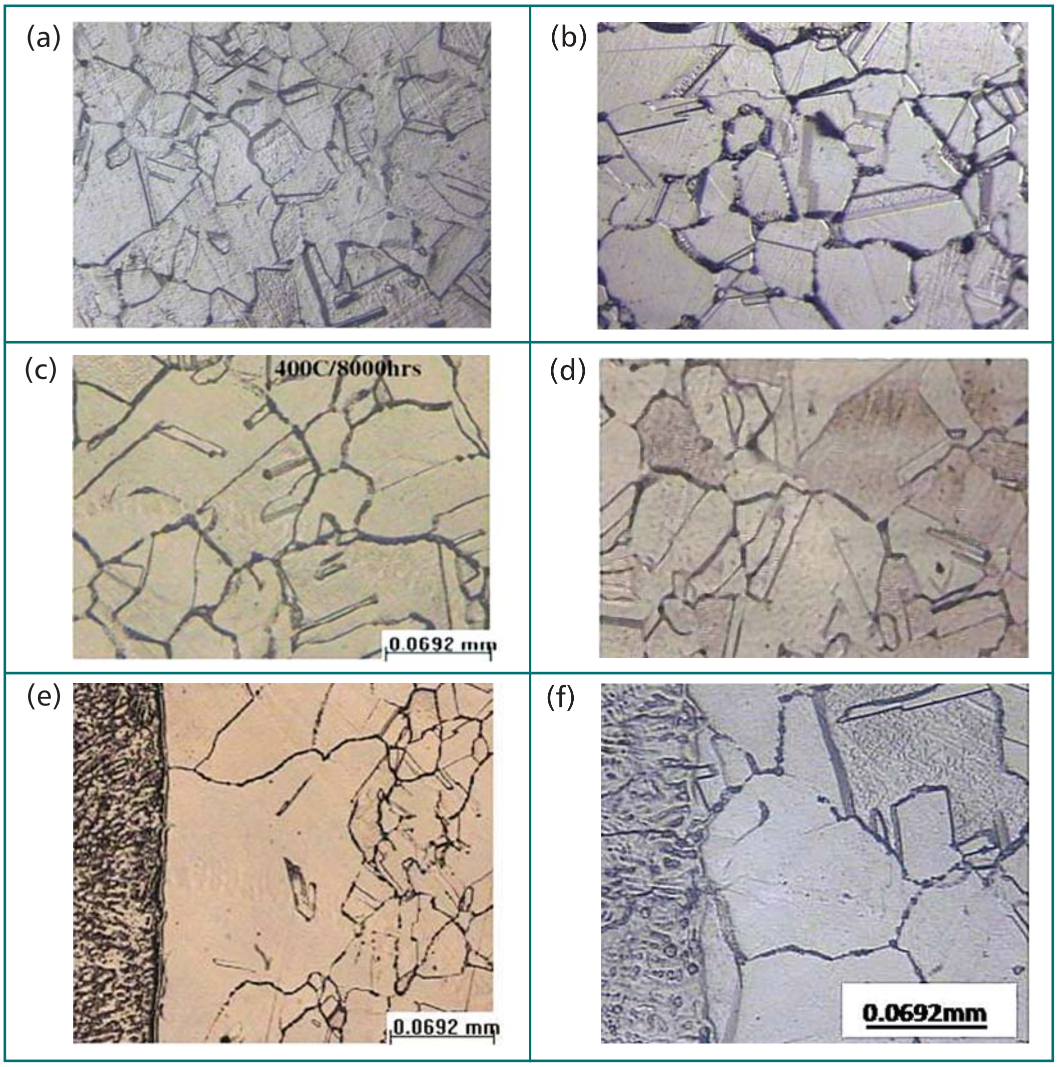

Fig. 1: Microstructure of oxalic acid etching test (a) As received (b) Sensitized at 675°C (c) Base, ageing at 400°C for 8000 Hours (d) Base, ageing at 450°C for 1300 Hours (e) Weld HAZ ageing at 400°C for 8000 Hours (f) Weld HAZ ageing at 450°C for 1300 Hours

to verify the kinetics of the sensitization mechanism close to the operating temperature. These results would be known later. The sensitization was quantified in terms of Degree Of Sensitization (DOS) using Double Loop Electrochemical Polarization Reactivation (DL-EPR) tests. This was supported by oxalic acid etching according to ASTM 262 practice A and ASTM 262 Practice E tests. The results of the D-EPR and oxalic acid etching tests obtained till now are shown in tables 2 and 3. Typical results of the microstructures of the virgin and aged samples are shown in Fig. 1.

DOS and microstructure (in 10 % oxalic acid solution) is correlated as (a) 0.01-0.1 % DOS corresponds to step structure, (b) 0.1-5 % to Dual structure and (c) more than 5 % as Ditch structure [7]. DOS below 5 % corresponding to dual structure is acceptable. Results in table 2 and table 3 show that DOS of weld HAZ increases with increase in ageing duration at given temperature. There is some scatter in the data because of the inhomogeneity in the chemical composition, which calls for some margins in the various element of the chemical composition. Microstructures of the oxalic acid etch test given in Fig. 1, show carbide precipitations along grain boundaries in aged samples for base and weld HAZ. Results of the tests on base and weld HAZ after accelerated thermal ageing, indicate that carbide precipitation along the grain boundaries is in acceptable limit. Therefore, the study carried out so far indicates that LTS may not be of concern for SS 304LN base and weld material within a time frame of 100 years. The tests are also planned under strained and simulated reactor environment, which will be very near to the actual conditions.

Low Temperature Embrittlement

The phenomenon of hot cracking or solidification cracking is of concern in austenitic stainless steel welds. The solidification cracking results from the segregation of low melting point liquid along the grain boundaries during last stage of solidification. If sufficient stresses are generated before the final solidification, boundaries may separate to form a crack. It has been known that presence of retained ferrite in the austenitic stainless steel weld effectively prevents hot cracking. The higher solubility of impurities in ferrite than in austenite, results in less segregation of low melting impurities, which helps in preventing hot cracking. Delta ferrite has lower thermal coefficient of expansion (α), which helps in reduction of thermal stresses. ASME Boiler and Pressure vessel code calls for minimum of 5% δ-ferrite (or 5 FN) in austenitic stainless steel weld, to avoid solidification cracking.

Transformation of this δ-ferrite into a brittle phase due to prolonged exposure to temperature of about 300 deg C can cause Low Temperature Embrittlement. It is well known that the kinetics of low temperature embrittlement is faster in the presence of Molybdenum [8].

LTE studies were carried out to confirm that austenitic stainless steel (SS 304LN) welded by E308L/ER308L, would not have a problem of loss in toughness during service of the plant. The ferrite content in the weld metal was in the range of 5-8 FN. These studies were performed on materials subjected to accelerated ageing by simulating time and temperature in such a way that the kinetics processes remained unaffected. The ageing durations planned are of 5000, 10000, 20000 and 50000 Hours at temperatures 400°C, 350°C and 300°C. Loss in toughness has been quantified by carrying out the impact test. At present, work has been completed for 5000 hours of ageing. The result indicates no reduction in toughness for the ageing duration of 5000 hours at various temperatures.

Welding Process Optimization

The issue of IGSCC can also be tackled by optimizing the welding process and technique, which will lead to reduction in heat input and residual stress.

The propensity to sensitization can also be reduced using high deposition welding process and narrow gap welding. Existing welding process (as per ASME Section IX) [9] used in welding of pipes is by GTAW forroot pass and SMAW for filling passes. Although fracture toughness properties of the GTAW are comparable to that of base metal (good for LBB), GTAW is a low deposition process leading to high heat input which is detrimental to sensitization resistance. Fracture toughness of the SMAW is inferior compared to that of base metal, although deposition rate is higher compared to that of GTAW. Welding process suitable for welding of pipes should have high deposition rate and comparable fracture toughness. A narrowgap technique gives additional margin against sensitization without compromising the fracture toughness. Hot Wire GTAW Process with Narrow Gap Technique is suitable for welding of pipes of austenitic stainless steel. Existing procedure and the work carried out on optimization of welding process and technique, is described below:

Residual stress evaluation

In order to demonstrate the benefits of narrow gap welding, residual stress evaluation was performed on a welded pipe. Pipe of 300NB Sch 120 was welded (manually) using most widely and versatile welding process, GTAW as root pass (few initial passes) and SMAW as filling passes. These welding processes are currently being followed in Indian nuclear power plants. Residual stress evaluations have been carried out on the following weld joints.

Manual SMAW with various groove angles (324 mm outer diameter pipe) shown in Fig. 2 as (a) Conventional groove with 75^0 included angle, (b) Narrow groove with 0^0 (width 16mm), (c) Narrow groove with 0^0 (width 13mm) and *Manual GTAW with conventional groove* (168 mm outer diameter pipe) were used for residual stress evaluation. Residual stress was measured using blind hole drilling method (as shown in Fig. 3) at weld root and top. Fig. 4 shows significant reduction in residual stress, resulting from narrow gap welding.

Mechanized hot wire GTAW with narrow gap technique and *conventional manual GTAW* were compared for residual stress. Residual stress and axial shrinkage in weld joints prepared by mechanized hot wire GTAW and conventional GTAW are shown in

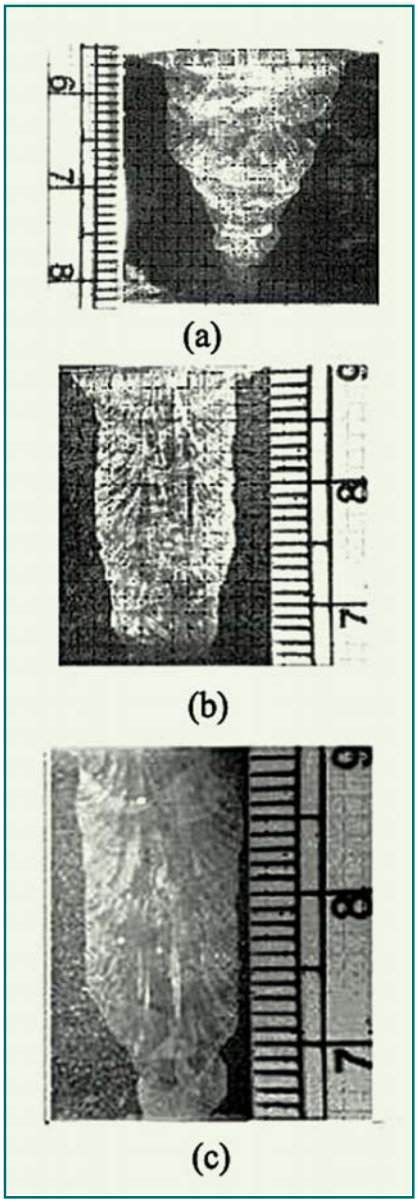

Fig. 2: Cross section of weld joints with different gap or groove widths

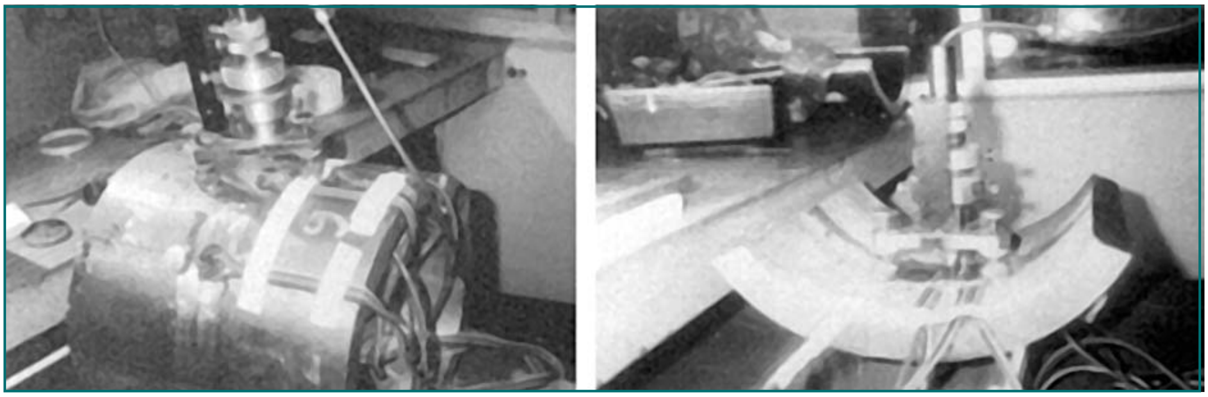

Fig. 3: Measurement of residual stress using blind hole drilling method

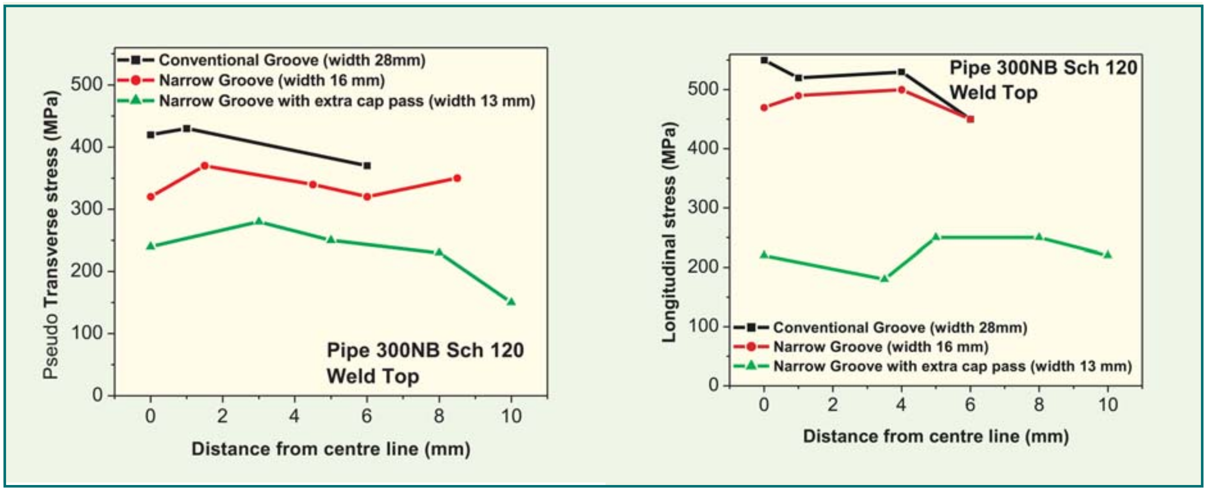

Fig. 4: Residual stress distribution

Figs. 5 and 6 respectively. Mechanized hot wire GTAW is a high deposition rate (three times that of conventional GTAW) welding process. Total heat input to the welding is also reduced due to high deposition rate, leading to reduction in propensity of weld HAZ to sensitization.

Figs. 5 and 6 show that residual stress and shrinkage in weld joints produced by mechanized hot wire GTAW are less as compared to that of conventional GTAW. Variation of residual stress in weld joints produced by mechanized hot-wire GTAW is also less as compared to that of manual GTAW.

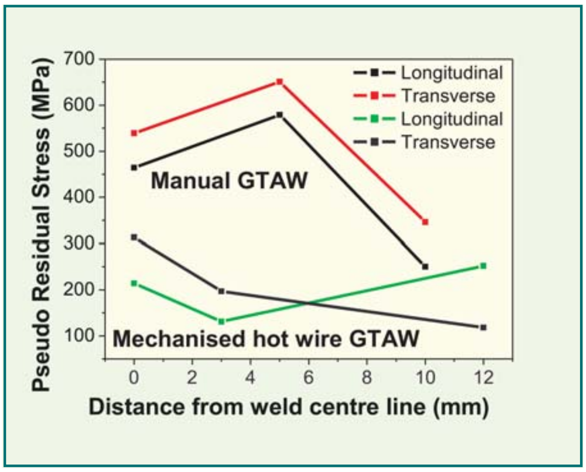

Fig. 5: Residual stress in conventional GTAW and hot wire GTAW

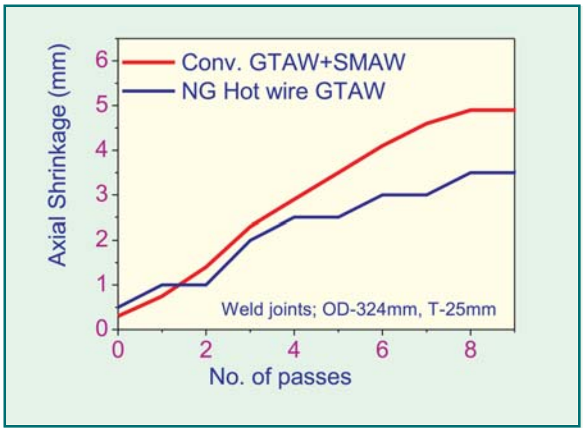

Fig. 6: Shrinkage in conventional GTAW and hot wire GTAW

Minimization of Sensitization in Weld HAZ

Sensitization of austenitic stainless steel material can be reduced, by material optimization (detailed in section 2) and weld optimization. Weld HAZ is subjected to temperature range of 500-800°C during heating and cooling. Increasing the cooling rate can reduce the chances of sensitization. Cooling rate (Fig. 7) of the weld HAZ in case of hot wire GTAW is 3 times faster as compared to that of manual GTAW. The temperature were measured using thermocouples at various distances from the weld center line. This is because of the lower heat input of 0.9 KJ / mm for hot wire GTAW and 1.89 KJ / mm for manual GTAW.

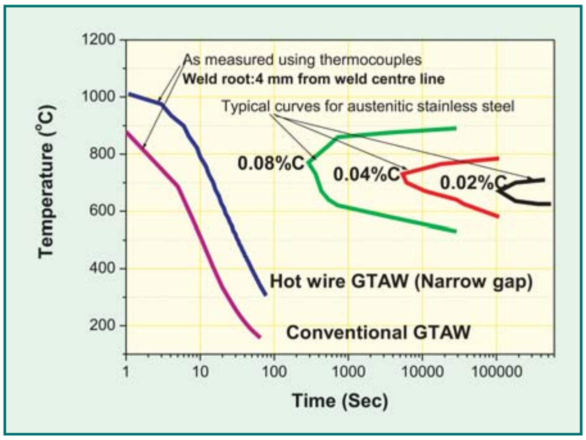

Fig. 7: Time-Temperature for material and cooling rate in weld HAZ

Fatigue and Fracture Toughness

It is desirable to have comparable fatigue and fracture properties for weld, with respect to base in order to maintain homogeneous characteristics of the material. Fatigue and fracture resistance of the welds were also quantified, by carrying out tests on specimens as per the guidelines of ASTM standard. The details of the results are described below:

Low Cycle Fatigue (LCF) and Fatigue Crack Growth Rate (FCGR) tests were carried out on specimens machined from the actual pipe welds. The location of specimen with respect to pipe weld is shown in Fig. 8. Result (shown in Fig. 9) shows that low cycle fatigue life of the weld joint (SMAW) is lower as compared to that of base metal. Tests (on compact tension

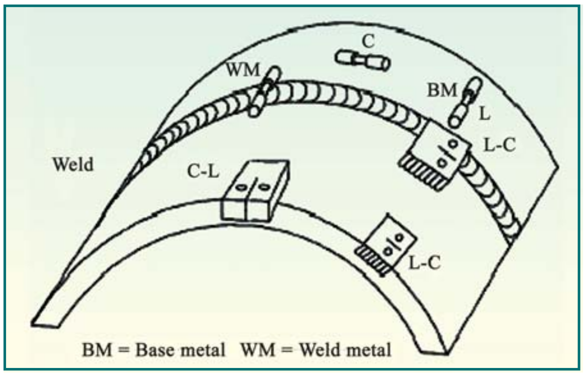

Fig. 8: Location of Round Tensile and CT Specimen

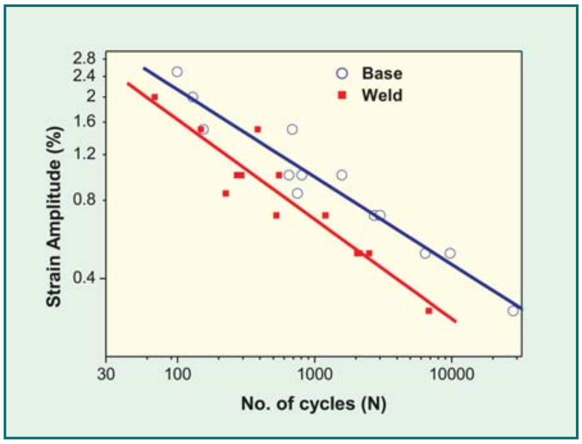

Fig. 9: Low cycle fatigue curve for the base and weld

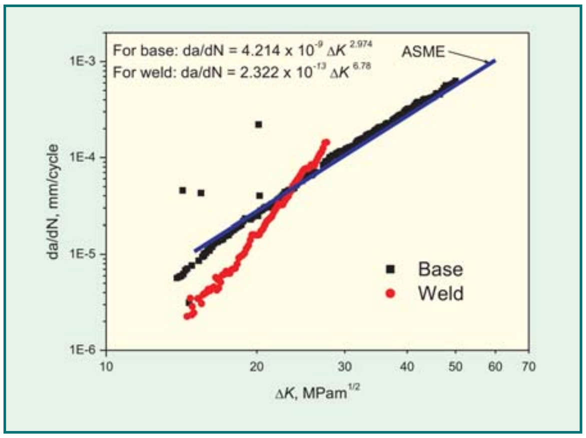

Fig. 10: Fatigue crack growth rate curve for base and weld

specimen) show higher FCGR for weld joints (SMAW) as shown in Fig. 10. FCGR was also been compared to that given in ASME Section XI. [10] and is shown in Fig. 10.

Fracture toughness tests require load and Crack Mouth Opening Displacement (CMOD) for fracture resistance characterization. Measured load versus CMOD curves for weld of GMAW and SMAW are shown in Figs. 11 and 12 respectively. Figures indicates that in case of weld (SMAW) there is rapid load drop as compared to base. This clearly shows that there is excessive crack tearing. GTAW has much higher crack tearing resistance as compared to SMAW. This observation is further

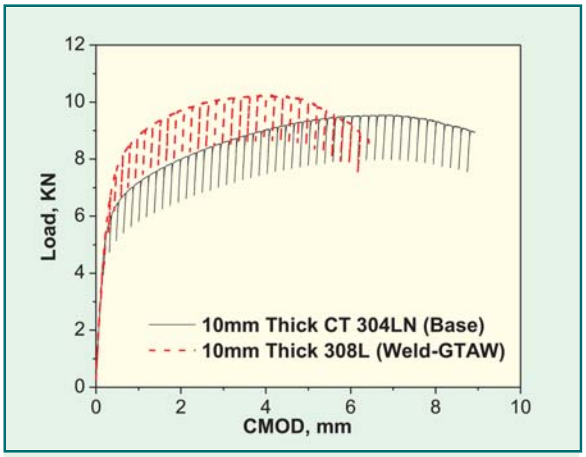

Fig. 11: Comparison of base and GTAW weld joint

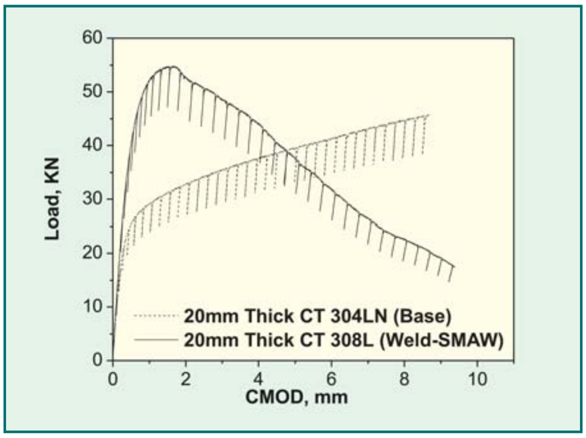

Fig. 12: Comparison of base and SMAW weld joint

highlighted in fracture resistance (J-R) curves shown in figure 13a. The figure clearly quantifies that fracture resistance of GTAW is significantly higher than that of SMAW. J-R curve of conventional and narrow grove weld joints are same (shown in Fig. 13 b).

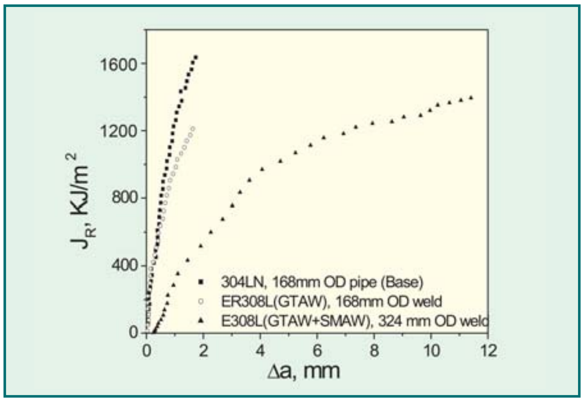

Fig. 13a: Comparison of J-R curves for SMAW & GTAW

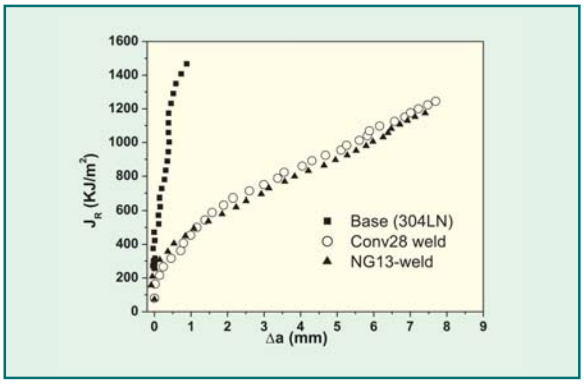

Fig. 13b: Comparison of J-R curves for SMAW & GTAW

Leak-Before-Break

The next step towards ensuring structural integrity, was demonstration of the ability of the piping to tolerate defects.

One of the ways of showing this, is the demonstration of leak-before-break. A combination of ductile material, not so hostile environment and a reliable leak detection system is necessary for this events.

This concept aims at the application of fracture mechanics principle to demonstrate that, pipes are very unlikely to experience sudden catastrophic break without prior indication of leakage. LBB evaluation is divided into three stages:

In the first level, it is shown that in view of the stringent specifications in material, design, fabrication, inspection and testing, there will be no crack initiation, thus avoiding the possibility of crack propagation. In this programme, material specification (as detailed in section 2) and fabrication (as detailed in section 4) were optimized to improve the quality of the material and weld to fulfill intended purpose. In addition to the mechanical properties, fatigue and fracture properties were evaluated.

In the second level of LBB evaluation, we postulate that a crack of certain length and depth has escaped detection. But, it can be shown that for the duration of plant life this crack will not grow enough to penetrate the wall, let alone cause catastrophic failure. This has been demonstrated by carrying out tests on actual pipes and pipe welds with postulated part through crack, to show that, there is no significant crack growth for the anticipated loading cycle during the plant life. This is described in detail in the section on Fatigue Tests.

In the third level, we postulate forced crack propagation to penetrate the wall and show that, the resultant through-wall crack is stable, produces leakage in sufficient quantity to enable detection and corrective action can be taken before it becomes critical. This has been demonstrated by carrying out tests on actual pipes and pipe welds with postulated through crack to show, that there is no unstable crack growth. This is covered in detail in the section Fracture Tests.

Description of Tests

Pipe material was austenitic stainless steel of SA312 type 304LN. Tests were carried out on seamless pipe and pipe weld of nominal outer diameter 324 mm and 168 mm having thickness of 27 mm and 14.3 mm respectively. The pipes were in solution-annealed condition. Gas Tungsten Arc Welding (GTAW) was used for welding of 6"NB pipe. GTAW (for root pass and few passes) and Shielded Metal Arc Welding (SMAW) (filling passes) were used for welding of 12"NB pipe. [11].

The test set up consists of servo hydraulic loading system, support for the pipes and various instruments for the measurement of data during the test. The support system for the pipe tests consists of two pedestals with pairs of rollers at outer span and inner span which simulates four point bending condition (Fig. 14). This type of loading ensures that notched section of the pipe is subjected to pure bending stress.

Fig. 14: Actual experimental set up for pipe

Pipes with part through and through-wall notch were subjected to fatigue loading till the crack has grown through thickness. Thereafter fracture tests were carried out on through-wall cracked pipes. The final through-wall crack size after fatigue test was taken as the initial crack size for the fracture tests.

During the test on through-wall cracked pipes, Load Line Displacement (LLD), load and Crack Mouth Opening Displacement (CMOD) were recorded. The crack growth at either tips of the through-wall crack, the load, angular rotation of the pipe about the support on either end and vertical deflection of the pipe at four locations along the length of the pipe were measured.

Fatigue tests (Level II of LBB)

In these tests, the pipes containing machined notch were subjected to cyclic loading. Number of cycles to crack initiation and the evolution of crack shape during crack growth were monitored. The results of these studies on crack resistance behaviour of the austenitic stainless steel pipe and pipe welds can be summarized as:

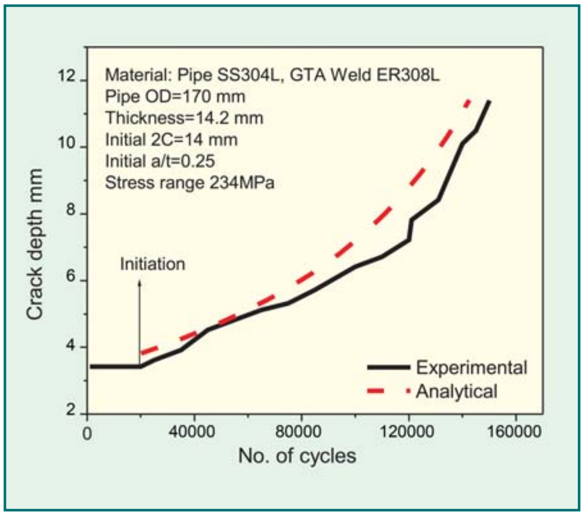

Fig. 15: Crack initiation and growth with no. of cycles

- For the typical stress range expected in the piping of AHWR, the number of cycles to crack initiation is very large as compared to the expected number of cycles (Fig. 15).

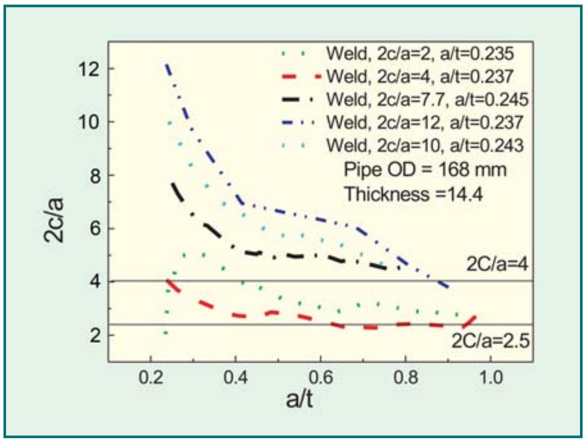

Fig. 16: Variation of aspect ratio with crack growth

- Fatigue crack growth also depends on the aspect ratio. Aspect ratio (2C/a) at the point of through thickness lies in the range of 3 to 4 irrespective of the initial notch aspect ratio (Figs. 16 and17). This provides justification for the usual assumption in LBB, that for a reasonable part through crack, the length at break out (leakage size crack) is not likely to be more than is normally assumed. Crack growth in surface direction is more for the aspect ratio greater than 4 compared to thickness direction. Notch of semi circular front (aspect ratio is crack length by crack depth=2) maintains its shape till through thickness (Fig. 17). Number of cycles required for crack to grow through thickness is very large as compared to those expected during plant life.

- The use of the fatigue crack growth curve given in ASME Section XI [10] will produce a conservative result (Fig. 18).

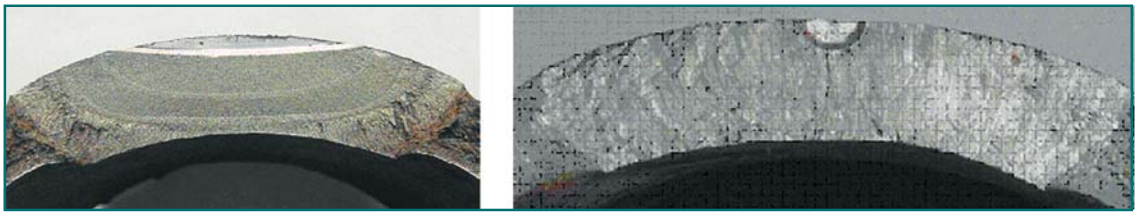

Fig. 17: Fracture surface showing crack shape during fatigue crack growth

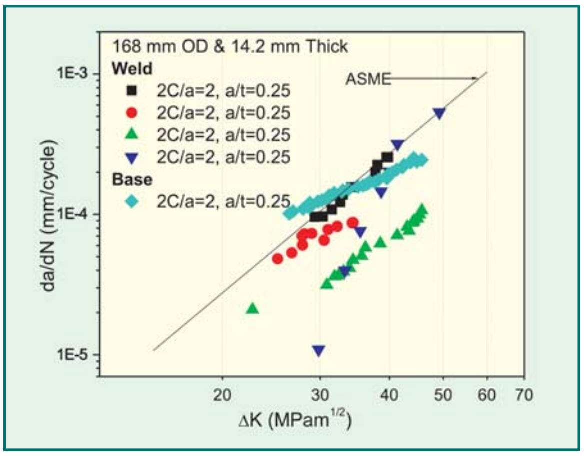

Fig. 18: Comparison of crack growth rate curve from pipe tests and ASME

Fracture Tests (Level III of LBB)

The fatigue test was continued till the crack grew through-wall. The pipe containing through-wall crack was subjected to monotonically increasing load till collapse. Applied bending moment versus bending rotation, applied moment versus crack extension and fracture resistance (J-R) curves for the pipe and pipe weld are shown in Figs. 19-21 for the 168 mm OD pipe and in Figs. 22-24 for 324 mm OD pipe. Figs. 25 and 26 are the photographs of the 168 mm OD pipe weld and base respectively. Similarly, Figs. 27 and 28 show the photographs of the 324 mm OD pipe weld and base.

1. Fracture resistance of pipe is superior as compared to pipe weld (Figs. 20 and 21, 23 and 24).

2. Initiation of crack growth occurred at a load lower than the maximum load bearing capacity of the pipe, e.g. the crack extension at maximum bending moment, in pipe and pipe weld for 168 mm OD pipe, are 4.5 and 8.5 mm respectively (Figs. 20, 23). This shows that failure is not due to plastic collapse alone and therefore fracture mechanics has a role in the prediction of instability condition in pipes.

3. Drop in bending moment after maximum moment is faster in weld (Figs. 19 and 22).

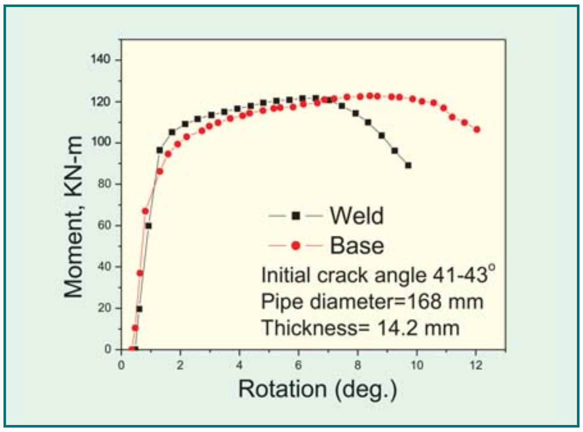

Fig. 19: Moment rotation curve - 168 OD

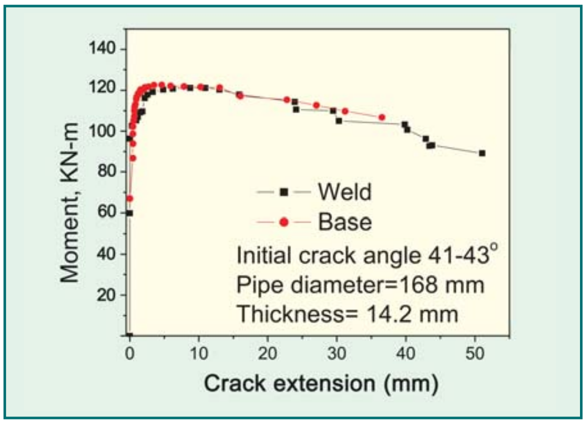

Fig. 20: Moment-crack extension 168 OD

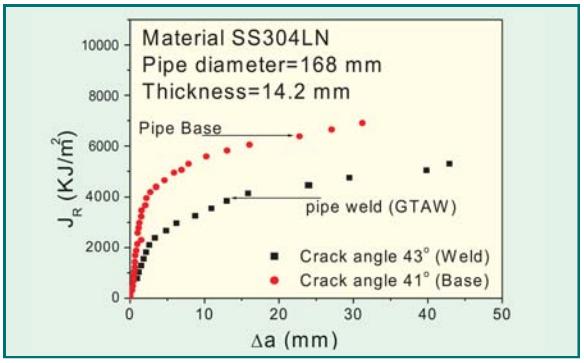

Fig. 21: J-R curve 168 OD

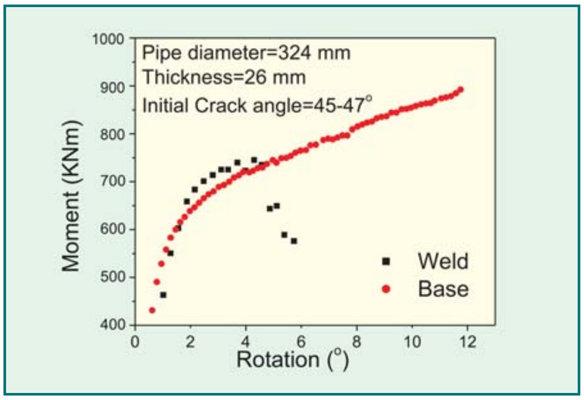

Fig. 22: Moment rotation curve - 324 OD

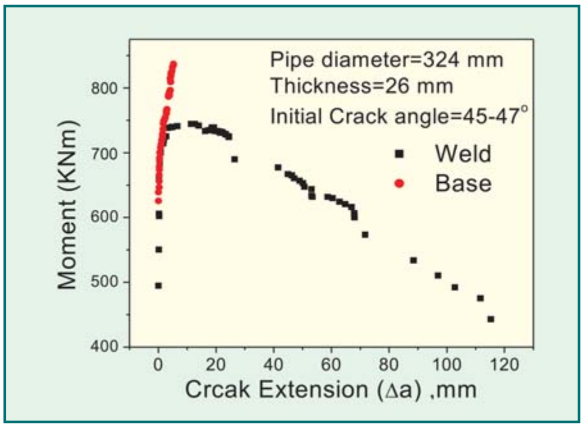

Fig. 23: Moment-crack extension 324 OD

4. In the case of 168 mm OD pipe (GTAW weld), the crack extension in pipe (base) and the pipe (weld) are comparable (Figs. 20, 21). But in case of 324 mm OD pipe (GTAW + SMAW) weld, the crack extension is much more than that seen in base (Figs. 23, 24). This indicates that fracture resistance of pipe and SMAW weld differ considerably whereas in case of GTAW weld, this difference is not significant. Thus there is a substantial incentive in employing GTAW for welding of SS pipes.

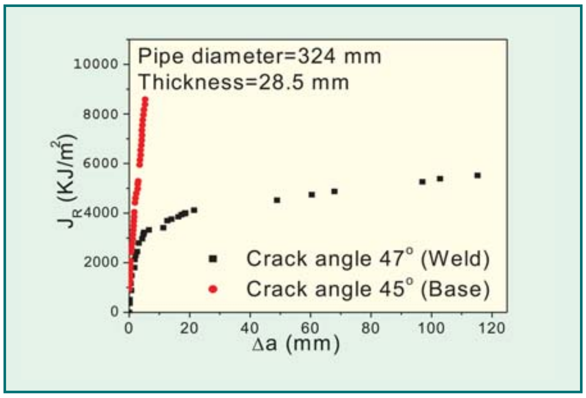

Fig. 24: J-R curve - 324 OD

Fig. 25: Pipe weld of 168 mm OD

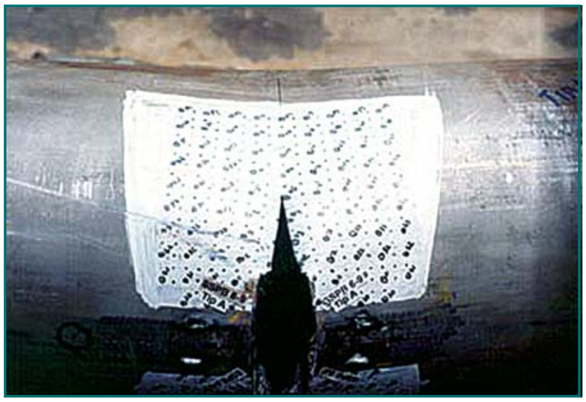

Fig. 26: Pipe base of 168 mm OD

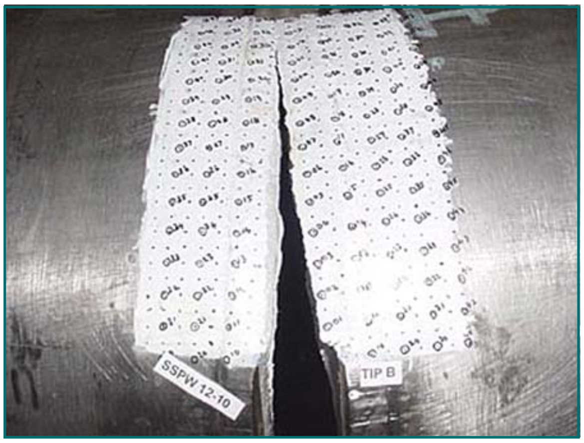

Fig. 27: Pipe weld of 324 mm OD

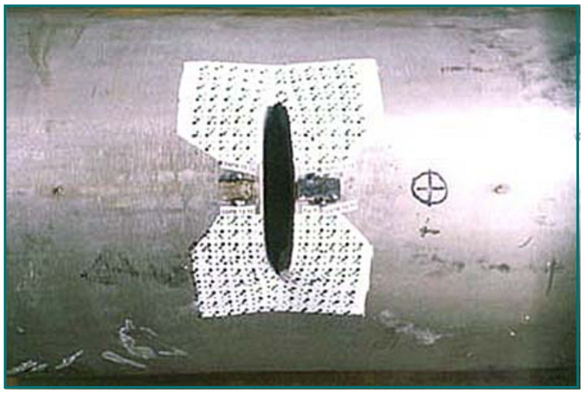

Fig. 28: Pipe base of 324 mm OD

Prediction of limit load

Limit load analysis is one of the simplest methods to predict the instability of the piping system. This is also known as net section collapse. Experimental maximum moment and the calculated limit moment for all the cases is given in Table 4. Analytical limit load (P_o) was calculated based on initial crack angle by expression,

$$P_o = (16\sigma_f R^2 t)/(Z\text{-}L)[\cos\{(a/2t)(\theta/2)\} - (a/2t)\sin\theta]$$

Where σ_f is flow stress i.e. average of yield and ultimate tensile strength of material in MPa, R is mean radius of pipe in mm, Z is outer span and L inner span in mm, θ is half the crack angle in degree, t is thickness in mm.

Limit loads were calculated based on both the yield strength (Column 5) and the flow stress (Column 6) of the material. Tensile properties (yield and ultimate tensile strength) of base were used for evaluation of limit load for pipe welds. It was seen that predicted limit load based on flow stress is comparable to the experimental value for base metal. But the predicted value is higher than experimental limit load by 2-12 % and 5-32% for 168 mm (GTAW) and 324 mm (GTAW + SMAW) welds.

The lower experimental limit load in comparison to the one predicted, is due to the substantial crack growth in welded pipes prior to attaining maximum moment. Existing limit load expression does not account for the crack extension or growth and therefore gives reasonable prediction for pipes as long as there is no crack extension. For welded pipes where crack extension occurs prior to net section collapse, this expression gives non-conservative prediction.

The results indicate that the limit load expression requires modification for using it for welds. Based on the results of the several pipe welds, existing expression for limit load evaluation for pipe can be modified by incorporating a multiplication factor for good prediction of limit load in case of pipe welds. The suggested facor is 0.85 for pipes welded using GTAW and 0.7 for pipes welded using GTAW + SMAW. Modified expression can be written as:

$$P_o = 0.85\,(16\sigma_f R^2 t)/(Z\text{-}L)[\cos\{(a/2t)(\theta/2)\} - (a/2t)\sin\theta]$$

for GTAW welds.

$$P_o = 0.70\,(16\sigma_f R^2 t)/(Z\text{-}L)[\cos\{(a/2t)(\theta/2)\} - (a/2t)\sin\theta]$$

for GTAW + SMAW welds.

Table 4: Comparison of experimental and analytical limit loads

Test no.*	Crack angle (2θ°)	σ_y (MPa)	σ_u (MPa)	Limit load, P_y (KN) using $\sigma_f = \sigma_y$	Limit load, P_f (KN) using $\sigma_f = 0.5(\sigma_y+\sigma_u)$	Maximum Experimental load, P_{max} (kN)	P_{max}/P_f	P_{max}/P_y
PW6-1	41.12	318	617	354.43	521.06	477.04	0.92	1.35
PW6-2	50.58	318	617	333.76	490.67	447.92	0.91	1.34
PW6-3	53.93	318	617	324.49	477.05	449.57	0.94	1.39
PB6-9	**43.65**	**318**	**617**	**266.45**	**391.72**	**384.71**	**0.98**	**1.44**
PW12-10	47.04	324	635	679.46	1005.56	810.76	0.81	1.193
PB12-12	**44.55**	**324**	**635**	**935.43**	**1384.39**	**1308.8**	**0.95**	**1.399**
PWTW6-6	102.46	318	617	230.17	338.38	295.528	0.87	1.283
PWTW12-11	65.96	324	635	818.88	1211.9	960.38	0.79	1.173
PWTW12-12	94.79	324	635	647.69	958.55	655.78	0.68	1.012

* PB6-Pipe base material-OD 6"; PW6-Pipe Weld material-OD 6"

Conclusions

1. Among the various low carbon grades of austenitic stainless steels viz. SS 304L, 316L, 304LN and 316LN, choice of SS 304LN is based on its satisfactory low temperature sensitization behaviour and superior low temperature embrittlement behaviour which are important for a targeted life of 100 years.
2. The IGSCC resistance is further improved by adopting high deposition rate (hot wire GTAW) process and narrow gap technique, which has shown reduced residual stresses as compared to conventional welding. Further during welding, the margin on sensitization in terms of time temperature (cooling rate) is higher in case of hot wire GTAW.
3. Gas Tungsten Arc Welding gives much better fracture resistance as compared to Shielded Metal Arc Welding.
4. A combination of narrow gap technique and hot wire GTAW will provide an added assurance against failure due to IGSCC/fatigue/fracture.
5. Number of cycles for crack initiation in AHWR piping is considerably higher than the number of cycles anticipated during the design life.
6. The use of the fatigue crack growth curve given in ASME Section XI will produce a conservative result where as Paris constants determined for this material using CT specimen give good prediction.
7. Crack growth in depth direction is more than that in length direction. Aspect ratio (2C/a) at the point of through thickness lies in the range of 3 to 4 irrespective of the initial notch aspect ratio, thus favouring Leak-before-break.
8. The load carrying capacity of a through-wall cracked pipe is higher than the maximum credible loading due to a Safe Shutdown Earthquake. Thus, AHWR piping has been shown to satisfy the Leak-before-break criterion.
9. Suitable multiplication factor has been suggested for prediction of limit load of pipe welds (GTAW and SMAW) based on flow stress of the base material.

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New Publication

HANDBOOK OF MEMBRANE SEPARATION: CHEMICAL, PHARMACEUTICAL AND BIOTECHNOLOGICAL APPLICATIONS.

Eds.

Anil Kumar Pabby
Bhabha Atomic Research Centre
PREFRE, Tarapur

Syed S. H. Rizvi and
Ana Maria Sastre

ISBN : 9780849395499
July 2008

This Handbook is a compilation of a series of peer-reviewed chapters, written by experts and professionals, on advances and applications in Membrane technology. It is divided into three sections; the first section deals with membrane applications in chemical and pharmaceutical industries and in conservation of natural resources; the second section covers membrane applications in biotechnology, food processing, life sicences and energy conversion; the third section deals with membrane applications in industrial waste management (including nuclear) environmental engineering and future trends in Membrane Science.

This Handbook will be particularly useful to non-experts and students, as it provides basic theoretical information as well as practical applications in Membrane Science and technology.

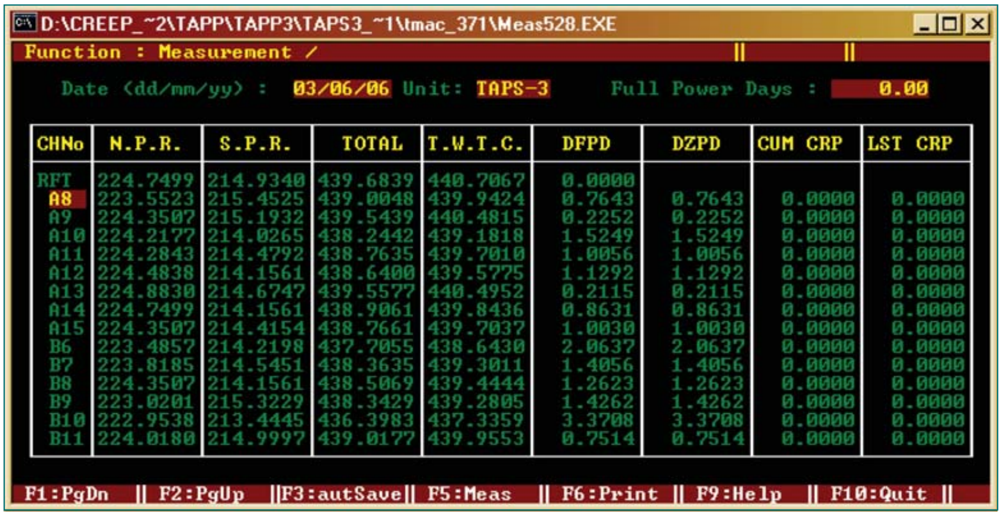
HANDING OVER OF THE TMAC SYSTEM TO TAPS 3 & 4

Axial creep monitoring of the coolant channels is required to be done, during every bi-annual shutdown in Pressurized Heavy Water Reactors. Previously the data was measured using Optical Method which was almost manual and had limitations like dependence on geometry lay out in fuelling machine vault, significant man-rem consumption and took about one week for measurement followed by calculation and report preparation. Hence a new system called TMAC (Technique for Measuring Axial Creep) was developed by the Refuelling Technology Division (RTD) BARC, to measure creep in all 220 MWe PHWRs. Fuelling Machines make contact with each channel to monitor the creep. The Z motion potentiometer is used as a sensor for the system. The system has been standardized for all 220 MWe plants of NPCIL.

NPCIL requested RTD to develop TMAC system for 540 MWe PHWR. As the 540 MWe reactor has a different lattice structure of coolant channels and also since there is difference in the dimension of coolant channel end fitting, the same system cannot be used. Hence a new version of TMAC was developed for 540 MWe reactors.

TMAC tool was developed as per the dimension of coolant channel and also compatible with 540 MWe Fuelling Machine. A microcontroller based Data Acquisition System was developed

Fig. 2 : TMAC tool compatible with 540 MWe Fuelling Machine



CHNo	N.P.R.	S.P.R.	TOTAL	T.W.T.C.	DFPD	DZPD	CUM CRP	LST CRP
RFT	224.7499	214.9340	439.6839	440.7067	0.0000			
A8	223.5523	215.4525	439.0048	439.9424	0.7643	0.7643	0.0000	0.0000
A9	224.3507	215.1932	439.5439	440.4815	0.2252	0.2252	0.0000	0.0000
A10	224.2177	214.0265	438.2442	439.1818	1.5249	1.5249	0.0000	0.0000
A11	224.2843	214.4792	438.7635	439.7010	1.0056	1.0056	0.0000	0.0000
A12	224.4838	214.1561	438.6400	439.5775	1.1292	1.1292	0.0000	0.0000
A13	224.8830	214.6747	439.5577	440.4952	0.2115	0.2115	0.0000	0.0000
A14	224.7499	214.1561	438.9061	439.8436	0.8631	0.8631	0.0000	0.0000
A15	224.3507	214.4154	438.7661	439.7037	1.0030	1.0030	0.0000	0.0000
B6	223.4857	214.2198	437.7055	438.6430	2.0637	2.0637	0.0000	0.0000
B7	223.8185	214.5451	438.3635	439.3011	1.4056	1.4056	0.0000	0.0000
B8	224.3507	214.1561	438.5069	439.4444	1.2623	1.2623	0.0000	0.0000
B9	223.0201	215.3229	438.3429	439.2805	1.4262	1.4262	0.0000	0.0000
B10	222.9538	213.4445	436.3983	437.3359	3.3708	3.3708	0.0000	0.0000
B11	224.0180	214.9997	439.0177	439.9553	0.7514	0.7514	0.0000	0.0000

Fig. 1 : DOS based Operator Interface

and assembled in-house. DOS based software TMAC ver 3.5 was developed, which generates report as per 540 MWe reactor lattice structure.

Fig. 3 : Data Acquisition Card for TMAC

An operation manual was prepared, containing concept and procedure of the technique. The system was successfully used in TAPS-3 & 4 for generating base data of creep measurement..

TAPS 3 & 4 persons were provided training on the usage of the system. System was also demonstrated on line by simulating measurement at Hall-7, BARC to TAPS 3 & 4 personnel. The system was handed over to the Station Director TAPS 3 & 4 on 19th March, 2008 by Head RTD, BARC at Engg. Hall-7, BARC.

Fig. 4: TMAC handing over to TAPS 3 & 4 From left to right Mr. R.K. Gargye, SD TAPS 3&4, Mr. Umang Mitter, SME(F) TAPS 3 & 4, Mr. S. Bhattacharya, RTD, BARC, Mr. Nageswara Rao, Director (Operation), NPCIL, Mr. R.G. Agrawal, Head, RTD,BARC Mr. R.J. Patel, Head FHDDS, RTD, BARC, Mr. K.B. Dixit, Director (Engg), NPCIL, Mr. Rites Ranjon, RTD, BARC.

MoU WITH INDIAN RUBBER MANUFACTURERS' RESEARCH ASSOCIATION (IRMRA)

It is proposed to use elastomer 'O' ring-based radial seal plugs, for closing pressure boundary of coolant channels, in the Advanced Heavy Water Reactor. Elastomer 'O' ring seal is preferable to metallic seal due to its better sealing properties, even with minor defects on the sealing surfaces. Presently elastomer compound suitable for reactor operating conditions of high pressure and temperature is not available in India. Therefore an elastomer compound needs to be developed indigenously. The compound should be radiation resistant and should not be corrosive to contacting materials. Once the compound is developed, it may be used for making any type of high temperature seal.

Indian Rubber Manufacturers' Research Association (IRMRA) is an ISO-9001 certified laboratory, affiliated to the Ministry of Commerce & Industry, Government of India, engaged in pursuit of higher research in rubber and polymer technology. IRMRA has extensive facility and experience in product development of rubber and polymer-based products.

An MoU was signed on 11th Sep, 2008 with IRMRA, for 'Scientific Collaboration to jointly develop a special elastomeric compound suitable for nuclear power plants to work in high temperature and pressure conditions'. Dr. S. K. Chakraborty, Acting Director, IRMRA and Mr. R.K. Sinha, Director, RDDG signed the MoU.

From left to right : Mr. B. Bhuyan, Sr. Sc. Officer, IRMRA; Mr. Suresh Chandran, Sr. Sc. Officer, IRMRA; Mr. K. Rajkumar, Asst. Director, IRMRA; Mr. R.G. Agrawal, Head, RTD; Mr. R.J. Patel, Head, FH D & D Section, RTD; Mr. R.K. Sinha, Director, RDDG; Dr. S.K. Chakraborty, Acting Director, IRMRA

NATIONAL SEMINAR ON OPERATION RESEARCH AND INNOVATIONS IN RADIATION PROTECTION AT NUCLEAR POWER PLANTS AND NUCLEAR FACILITIES

The Health Physics Division, Bhabha Atomic Research Centre, Mumbai and Nuclear Training Centre, Tarapur Atomic Power Station 3 & 4, Tarapur, had organized a National Seminar on Operation Research and Innovations in Radiation Protection at Nuclear Power Plants and Nuclear Facilities, at Nuclear Training Centre, Tarapur Atomic Power Station 3 & 4, Tarapur during June 18-19, 2008. The seminar was sponsored by the Board of Research in Nuclear Sciences and the Indian Nuclear Society, Mumbai.

The national seminar was organized to share innovations in radiation protection and application of operation research during construction, commissioning and operation of the nuclear power plants and nuclear facilities. The seminar provided ample opportunity to the operation, maintenance specialists and radiation protection professionals in exchanging innovations in the field of radiation protection.

Presentations included automation of radioisotope production using remote handling robotics, to help in minimizing radiation exposure. Papers related to regulatory aspects and radiological surveillance for industrial radiography at nuclear power plants and projects were also covered. Innovations in radiation protection training programme involving model rooms for the demonstration of radiation monitoring, dose monitoring and use of protective equipment with animated system flow sheets in different plants, were highlighted.

Dose reduction techniques and strategies in radiation hotspot management, ALARA job plans, pre job briefing, just-in-time briefing, exposure control during biennial shut downs in nuclear power plants were discussed. Developments and Innovations carried out in the areas of online dose management system, use of barcode system in internal dose assessment, network based and KIOSK based radiation data information system were implemented in many nuclear power plants, for prompt communication of radiological information and exposure control. Developments in radiation data acquisition system for online monitoring of radiation levels in and around nuclear power plants, have resulted in saving of productive collective dose.

The challenging task of conforming to international standards in the field of radiation protection, was in the availability of radiation monitoring instruments calibration systems, in nuclear power plants. The functional details of the system installed at TAPS 3 & 4 were shared with other participants. The additional use of online continuous particulate in air monitor for detecting air activity and material contamination assessment at the final check points, helped in enhancing radiation safety. Software programmes were developed and were being used for information generation and radionuclide analysis in the system samples, contaminated system equipment, handling and assessing tritium in large number of samples, data analysis and computing the bioassay sample submission compliance for internal dose evaluation were made easy.

About 100 participants benefited from the presentations and deliberations during the seminar.

The participants included health physics professionals and ALARA Coordinators from all Nuclear Power Plants, Specialists from Radiation Safety Systems Division, BARC and Health Physics Division, BARC Mumbai, BARC Tarapur facilities, NPCIL Head office and experts from Atomic Energy Regulatory Board (AERB).

There were 50 contributory papers on Innovations and developments in radiation protection and studies on radiological safety aspects. 38 papers were selected for presentation in the two days programme. Inaugural address was given by Mr. O.P.Goyal, Site Director and Tarapur Site, Maharashtra.

Presentations from BARC Tarapur facilities included developments in air born activity monitoring systems at A3F and estimation of dose rate buildup on the product drum.

Presentation from BARC Mumbai covered review of operation research in radiation protection during construction, commissioning and operation stages, Safety analysis of the fuel handling facilities in the SFSB, diffusion estimates for KKNPP atmospheres, Gamma dose rate on PHWR fuel bundles and shielding design of high level waste samples.

Forthcoming Conference

DAE-BRNS Conference
on
"50 years of Nuclear Grade Uranium Metal Production"
(UMFP-2009)

In the present context of expanding nuclear programme in India, the safe and successful completion of 50 operating years of uranium metal production unit is indeed an appropriate occasion to celebrate. Coincident with the birth centenary year of Dr. Homi Jehangir Bhabha. The one-day DAE-BRNS conference is being organised on the 31st of Jan. 2009, at the CC auditorium, BARC, Trombay, to celebrate Golden Jubilee of Uranium Metal Production.

The first conference on uranium in the centre was held in 1989 and several developments have taken place since then. Being the second conference on this topic in last 50 years, around 400 delegates from different operating nuclear plants of DAE, Industries, Educational Institutes, Research and Development Organizations, including leading experts in the notional fields, are expected to participate in this momentous conference.

Topics to be covered: Technical developments and Reminiscences on Uranium Exploration (T-1); Uranium Mining (T-1); Uranium Milling (T-2); Uranium Refining (T-3); Processing of secondary sources of uranium (T-3); Processing and production of various uranium compounds (T-4); Various analytical techniques in U-analysis (T-5); Waste management and environmental management in U-industry. (T-6); Indigenous technology and Engineering developments (T-7).

Registration : On or before 15th Jan., 2009

For further details, one may contact

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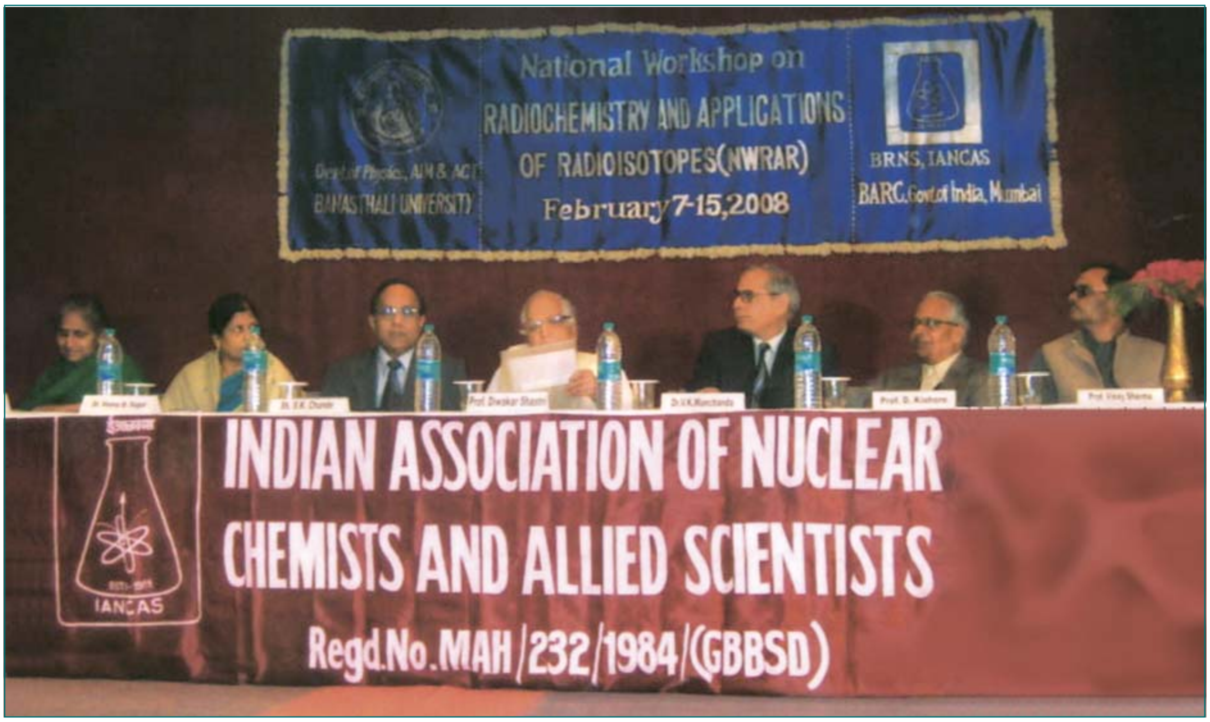
THE 66TH BRNS-IANCAS "NATIONAL WORKSHOP ON RADIOCHEMISTRY AND APPLICATIONS OF RADIOISOTOPES" : A REPORT

The BRNS-IANCAS workshop was jointly organized by the "Indian Association of Nuclear Chemists and Allied Scientists" (IANCAS) and Department of Physics, AIM&ACT, Banasthali University during 7-15 Feb. 2008. Prof. Rekha Govil, Dean, AIM & ACT and Convener of the workshop welcomed all the resource persons from BARC, participants and students.

In his talk on the activities of IANCAS, Dr. V.K. Manchanda, President, IANCAS and Head, Radiochemistry Division, BARC emphasized the need for energy in general and nuclear energy in particular. The association celebrated its silver Jubilee in January 2008 and has been playing an important role in popularizing nuclear science in general and the discipline of radiochemistry in particular. Mr. S.K. Chande, Vice-chairman, Atomic Energy Regulatory Board (AERB) discussed about the Indian nuclear power programme. He stressed the importance of safety standards in nuclear industry. He stated that in the history of nuclear industry, there have been only two major accidents as compared to many more



Inauguration: (L-R) Prof. (Smt.) Rekha Govil, Dean, AIM & ACT, Dr. Veena Sagar, BARC, Mr. S.K. Chande, Vice-Chairman, AERB, Chief Guest from IANCAS, Prof. Diwakar Shastri, Dr. V.K. Manchanda, President, IANCAS, Prof. D. Kishore and Prof. Vinay Sharma

At the Valedictory function : (L-R) Dr. Veena Sagar, Coordinator, IANCAS, Prof. (Smt.) Rekha Govil, Mr. B.K. Sen, Head, PDD, BARC & Chief Guest from IANCAS, Prof. Chitra Purohit, Mr. L.K. Nanda, Prof. D. Kishore and Prof. Vinay Sharma

during the same period. However, nuclear industry worldwide has further enhanced safety standards and regulatory aspects to ensure that this industry is safe. Mr. Chande was very appreciative of the culture developed in Banasthali in the staff as well as in the students.

Dr. Veena Sagar, Co-coordinator of Workshop presented the workshop programme. There were 5 special lectures by Mr. Chande of AERB, Dr. Manchanda, Dr. Meera Venkatesh, Mr. Kanwar Raj and Mr. B.K. Sen on 1.Safety Standards in nuclear power plants, 2. DAE activities at a glance, 3. Applications of Radioisotopes for the societal benefit, 4. Nuclear waste management and 5. Production & Applications of Radioisotopes in Industry, respectively.

Mr. B.K. Sen, Head, Produuct Development Division, BARC was the Chief Guest during the valedictory function and handed over the equipment to the host institute, to encourage them to continue the work initiated by IANCAS in popularizing Nuclear Chemistry.

In addition to the main workshop, there was a lecture-cum-demonstration programme for the students of 11^{th}, 12^{th} standard and also for graduates and post graduates.

Prof. Diwakar Shastri gave his blessings for the success of the workshop. At the end, Dr. Vimal Vyas, Secretary NWRAR, gave vote of thanks.

Dr. Veena Sagar and Dr. K.V. Lohitakshan were the coordinators and Dr.P.K.Pujari, Mr. K. Sudersan, Dr. Y.P. Naik, Ms. Sashikala Ojha, Dr. D.G. Phal from BARC and Mr. Chandan Kumar from BRIT were the other resource persons.

DAE - BRNS THEME MEETING TO DISCUSS INDIAN PARTICIPATION IN PANDA AT GSI

The Facility for Antiproton and Ion Research (FAIR) is an international large scale research and infrastructure to be built near Darmstadt, Germany. When commissioned , a few years from now, FAIR will be a world leading facility, providing international science community precision beams, of antiproton and rare isotope beams at unprecedented intensities. In addition to Nuclear and Hadron Physics research, this facility will be of interest to Plasma Physics, Astrophysics, Biophysics and Material Science communities. Broadly speaking, it is proposed to have three major detector development programmes at FAIR, driven by Physics interest related to Compressed Baryonic Matter (CBM), antiProton ANnihilation at DArmstadt (PANDA) and NUSTAR. India has signed an MoU with FAIR for Indian participation through "in kind" contribution towards development of accelerator, detector and sub-systems. The Department of Science and Technology GOI is the nodal agency from India. In the recently held meeting of the DAE-DST coordination committee, chaired by the secretaries of both the departments, it was decided that Indian scientists and engineers would participate in the R&D (accelerator, detector and sub-systems) programmes for FAIR at GSI. In order to identify the areas of R&D towards our contribution to PANDA based on our interest and expertise, a theme meeting on this topic, funded by DAE - BRNS was held at the Multipurpose Hall of Training School Hostel on April 15 and April 16, 2008. Prof. Ulrich Weidner (spokesperson for the PANDA Experiment) and Prof. James Ritman, Director IKP-I Forschungszentrum Juelich participated in this meeting as invitees. About 30 participants from DAE, IIT and universities participated in this meeting. Dr. P. Asthana represented DST.

The objective of this theme meeting was to initiate discussion to identify R & D areas for Indian participation in building PANDA and later Physics experiments with the same. India's involvement in detector construction and physics simulation related to the anti-proton physics programme was discussed. Various components of the PANDA detector, for which responsibilities could be taken up by the Indian participants, were also identified. It was proposed to hold regular yearly schools with selected speakers from India and abroad, on the Physics programme of the PANDA detector.

Dr. S. Kailas, BARC was elected as the Spokesperson for the PANDA collaboration from India.

CHARACTERIZATION AND SOURCE IDENTIFICATION OF PARTICULATE AIR POLLUTION IN THE ASIAN REGION : IAEA / RCA PROJECT PLANNING MEETING

The first IAEA/RCA Project Planning Meeting of the RCA Project on "Characterization and Source Identification of Particulate Air Pollution in the Asian Region"(RAS/7/015) was held from 21-24, August, 2007 in Goa. The meeting was attended by 15 participants from 13 countries Australia, Germany, China, India, Indonesia, Malaysia, Mongolia, Myanmar, Philippines, Singapore, Sri Lanka, Thailand and Vietnam.

Dr. Andrzej Markowicz of IAEA delivered the opening remarks on the first day at the opening session, on behalf of IAEA. Mr. H.S. Kushwaha, Director, Health Safety and Environment Group, BARC in his inaugural address stressed on the need for comprehensive understanding of the particulate pollution, their sources and health effects. On behalf of the organizing committee Mr. V.D. Puranik, Head, EAD welcomed all the participants and gave his remarks on the

Inaugural Session of IAEA/RCA Project Planning Meeting. On the dais from left to right Dr. (Ms.) G.G. Pandit, National Project Co-ordinator of India, Dr. Andreas Markwitz, Lead Country Co-ordinator of the Project, Mr. H.S. Kushwaha, Director, Health Safety and Environment Group, BARC, Dr. Andrzej Markowicz of IAEA and Mr. V.D. Puranik, Head, Environmental Assessment Division, BARC.

preliminary groundwork carried out in organizing the meeting. Dr. Andreas Markwitz of New Zealand who is Lead Country Co-ordinator of the Project gave a brief review of the earlier IAEA project (RAS/7/013) carried out in particulate air pollution and about the objectives of the current project. Dr.(Ms.) G.G. Pandit, Head, EMAS, EAD who is the National Project Co-ordinator of the Project h proposed the vote of thanks.

The technical sessions commenced soon after a brief inaugural session.

Dr.Andreas Markwitz who is the Lead Country Co-ordinator for the project acted as a Chairperson during the proceedings of the meeting. Two scientists from National Environmental Engineering Research Institute and one scientist from Goa State Pollution Control Board participated in the meeting as End-Users. Involvement of End-users is one of the objectives of the project or implementation of the project outcomes at the National level.

Session one on the first day involved presentations on status of research in particulate air pollution by a scientist the from National Environmental Engineering Research Institute (NEERI), Mumbai Zonal Laboratory and status of air pollution levels by Chairman, Goa State Pollution Control Board.

Dr. P.K. Hopke from Clarkson University, USA presented the impact of air particulate matter on human health and Prof. D. Cohen of Australia introduced concepts on air particulate matter pollution and visibility.

On the second day all the participants presented their country proposals of the project and Dr. P.K. Hopke who is the consultant for the current project reviewed the data of all the participating countries in his presentation.

A special discussion was held on involvement of end-users in the current project to achieve the proper utilization of the data generated at national level and also train the utilization of softwares like Positive Matrix Factorization and other receptor models for source identification and apportionment which will be useful for air quality management programmes. On third and fourth day, a work plan was chalked out for the project period 2008-2011 and discussion on data co-ordination and management and reviewed the outcomes, outputs, performance indicators and means of verification.

A group photograph of the participants and faculty

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

डॉ. सुनीता सिंह, जी. श्रीधर, वी.एस. रावत, एन.ओ. कवाडे, ए.एस. रावत, एस.के. मिश्रा एवं डॉ. एल.एम. गंतायत द्वारा लिखित "परफोरमन्स करेक्टरस्टिकस ऑफ रिमोटली ट्यूनेबल, हाई रेपेटिशन रेट, कॉपर वेपर लेज़र पंप्ड सिंगल लांगिट्यूडिनल मोड डई लेज़र" नामक शोध-पत्र को "फिज़िक्स एन्ड टेक्नालोजी ऑफ लेज़रस" के स्तर का श्रेष्ठ पोस्टर पुरस्कार से सम्मानित किया गया। यह शोध-पत्र दिसंबर 17-20, 2007 के दौरान एम.एस. यूनिवर्सिटी ऑफ बरोडा, वडोदरा में आयोजित डीएई-बीआरएनएस नैशनल लेज़र सिम्पोज़ियम (एनएलएस-7) मे प्रस्तुत किया गया था।

The Best Poster Paper Award in the category "Physics & Technology of Lasers" was awarded to Dr. Sunita Singh, G.Sridhar, V.S. Rawat, N.O. Kawade, A.S. Rawat, S.K. Mishra and Dr. L.M. Gantayet for their paper entitled, "Performance Characteristics of Remotely Tunable, High Repetition Rate, Copper Vapor Laser Pumped Single Longitudinal Mode Dye Laser". This paper was presented at the DAE-BRNS National Laser Symposium (NLS-7) held between December 17 to 20, 2007 at M.S. University of Baroda, Vadodara.


Dr. Sunita Singh

डॉ. सुनीता सिंह भाभा परमाणु अनुसंधान केंद्र के एल एन्ड पीटी प्रभाग के विज़िब्ल लेज़र एन्ड ऑप्टिक्स अनुभाग के अध्यक्ष है। इन्होंने हाई एन्ड लो पॉवर, पलस्ड, सीडब्ल्यू, पोलिमरिक डाइ लेज़रस एन्ड इलेक्ट्रोन ऑप्टिक्ल इमेजिंग डिवाइसिज़ एन्ड स्ट्रीक केमराज़ के विकास पर काम किया है। लंदन के इम्पीरियल कॉलेज में कॉमनवेल्थ विद्वान की हेसियत से इन्होंने (पहली बार) वर्ष 1980 में एक सीपीएम रिंग पल्सड डाई लेज़र में अल्प कालावधि का प्रदर्शन किया। इस समय डिज़ाइन, डेवलोपमेंट, एन्ड डेलिवरी ऑफ ट्यूनेबल, सिंगल लांगिट्यूडिनल मोड, हाई पॉवर, एन्ड हाई रेपिटिशन रेट डाई लेज़र फेसिलिटी फॉर लेज़र बेस्ड् सेपरेशन प्रोसेस इनकी रुचि के क्षेत्र में सम्मिलित है।

Dr. Sunita Singh heads the Visible Laser & Optics Section in L&PT Division of BARC. She has worked in the areas of development of high and low power, pulsed, CW, polymeric dye lasers and electron optical imaging devices and streak cameras. As a Commonwealth Scholar in Imperial College, London in 1980, she demonstrated (for the first time) short duration pulses in a CPM ring pulsed dye laser. Her current interests encompass design, development and delivery of tunable, single longitudinal mode, high power, and high repetition rate dye laser facility for laser-based separation process.


G. Sridhar

श्री. जी. श्रीधर ने भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र से 39वें बैच से सफलता पूर्वक प्रशिक्षण प्राप्त करके वर्ष 1996 में एल एन्ड पीटीडी में कार्यारंभ किया। ये हाई पॉवर, हाई रेपिटिशन रेट सीवीएल पंपड सिंगल लांगिट्यूडिनल मोड डाई ओसिलेटर -एम्पिलिफायर सिस्टमस के विकास में व्यस्त हैं। थियोरिटिक्ल एन्ड एक्सपेरिमेंटल स्टडीज़ ऑफ ट्यूनेबल लेज़रस एन्ड एसोसिएटिड सिसटम्ज़, पोलिमेरिक

सोलिड स्टेट डाई लेज़र्स, लेज़र एटम इन्टरेक्शन आदि इनकी रुचि के क्षेत्र में सम्मिलित हैं।

Mr. G. Sridhar joined L&PTD in 1996 from the 39th Batch of BARC Training School. He is involved in developing high power, high repetition rate CVL pumped Single Longitudinal Mode dye Oscillator-Amplifier systems. His fields of interest include theoretical and experimental studies of tunable lasers and associated systems, polymeric solid state dye lasers, laser atom interaction.

Vinod Singh Rawat

श्री. विनोद सिंह रावत ने वर्ष 1998 में आई आई टी देहली से इंसट्रुमेंट टेक्नॉलोजी मे एम.टेक प्राप्त किया। इन्होंने वर्ष 1998-99 में भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र से ओसीईपी के 8 वें बैच से प्रशिक्षण प्राप्त करके सितंबर 1999 को एल एंड पीटीडी में कार्यारंभ किया। ट्यूनेबल लेज़रस सिसटम, विषेशकर सिंगल लांगिट्यूडिनल मोड (एसएलएम) पलस्ड डाई लेज़र, वेव लेन्गथ लोकिंग, डिजांइनिंग ऑफ ऑप्टो-मेकानिकल कॉम्पोनंनटस, ऑप्टिकल इन्सट्रुमेंटेशन, ऑप्टिकस डिज़ाइन, लेज़र बीम डाइग्नोस्टिक सिस्टम, वाइब्रेशन एनालिसिज़, एवं फ्लो विजुवलाइज़ेशन इन डाइ सेल्स इनकी अनुसंधान रुचि में सम्मिलित हैं।

Mr. Vinod Singh Rawat received his M.Tech in Instrument Technology from IIT Delhi in 1998. He had joined L&PTD on 1st September 1999 after graduating from the 8th Batch of OCEP of BARC Training School in 1998-99. His research interests are tunable laser system particularly a Single Longitudinal Mode (SLM) pulsed dye laser, wavelength locking, designing of opto-mechanical components, optical instrumentation, optics design, laser beam diagnostic system, vibration analysis, and flow visualization in dye cells.

Nitin O. Kawade

श्री. नितिन ओ. कवाडे ने आई आई टी देहली से इंसट्रुमेंट टेक्नॉलोजी में एम.टेक की डिग्री प्राप्त की। इन्होंने भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र के 41वें बैच से प्रशिक्षण प्राप्त करके सितंबर 1998 को भाभा परमाणु अनुसंधान केंद्र में कार्यारंभ किया। लेज़र बेस्ड् इन्सट्रुमेंटेशन, एवं डाई लेज़र कंट्रोल, एमबेडिड, रियल टाइम सिसटमस एवं पीआइवी इनकी अनुसंधान रुचि में सम्मिलित हैं।

Mr. Nitin O Kawade received his M.Tech in Instrument Technology from IIT Delhi. He joined BARC on 1st September 1998 after graduating from 41st Batch of BARC Training School. His research interests are laser-based Instrumentation and dye laser control, embedded, real time systems and PIV.

Aseem Singh Rawat

एलेक्ट्रानिक इन्जीनियर, श्री. असीम सिंह रावत भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र के 35वें बैच से एल एंड पीटी प्रभाग में कार्यरत हैं। इनकी रुचि क्षेत्र में लेज़र बेस्ड् इन्सट्रुमेंटेशन सम्मिलित हैं। डिज़ाइन एन्ड डेवलोप्मेंट ऑफ लेज़र स्केन डाया गेज, लेज़र सर्फ चैक, लेज़र वेलोसिटी मीटर, रिबाउंड वेलोसिटी मीटर में आप व्यस्त हैं। आप टेक्नॉलाजी ट्रांसफर ऑफ लासकन डाया-गेज, सप्लाइ ऑफ लेज़र सर्फ चैक टु एमपीडी-बीएआरसी एन्ड लेज़र वेलोसिटी मीटर टु डीएमआरएल, डीआरडीओ, हैदराबाद में व्यस्त थे। इस समय ये फ्लो विजुवलाइज़ेशन यूज़िंग पीआइवी, डिसटंस एंड लेवल मेजरमेंट युजिंग ऑप्टिकल ट्राएंगुलेशन टेक्नीक एन्ड लेज़र

बीम डाइगनोस्टिक इन्सट्रूमेंटस पर कार्यरत हैं।

Mr. Aseem Singh Rawat is an electronics engineer working in L&PT Division, BARC and is from the 35th Batch of Training School. His field of interest is laser-based instrumentation. He has been involved in the design and development of laser scan dia gauge, laser surf check, laser velocity meter, Rebound velocity meter. He was involved in technology transfer of lascan dia-gauge, supplyof laser surf-check to MPD, BARC and laser velocity meter to DMRL, DR DO, Hyderabad. Presently, he is working on flow visualizationusing PIV, distance and level measurement using optical triangulation technique and laser beam diagnostic instruments.

Suman K. Mishra

श्री. सुमन के. मिश्रा भाभा परमाणु अनुसंधान केंद्र के लेज़र एन्ड प्लाज्मा टेक्नॉलाजी प्रभाग में वर्ष 2004 से ट्यूनेबल डाई लेज़र सिसटमस पंपड बई कॉपर वेपर लेज़रस के क्षेत्र में कार्यरत हैं। इन्होंने वर्ष 2002 में भाभा परमाणु अनुसंधान केंद्र के ईंधन रसायन विज्ञान प्रभाग में कार्यारंभ किया। ट्यूनेबल लेज़रस एन्ड एसोसियेटिड सिसटम्स, एचपीएलसी एवं मॉस स्पेक्ट्रोमीटरी इनकी रुचि क्षेत्र में सम्मिलित हैं।

Mr. Suman K. Mishra is working in Laser & Plasma Technology Division, BARC, since 2004 in the field of Tunable Dye Laser systems pumped by Copper Vapor Lasers. He joined the Fuel Chemistry Division, BARC, in 2002. His areas of interest include Tunable Lasers and associated systems, HPLC and Mass Spectrometry.

डॉ एल.एम.गंतायत भाभा परमाणु अनुसंधान केंद्र के बीटीडी वर्ग के एक प्रतिष्ठित वैज्ञानिक हैं। इन्होंने सेपरेशन प्रोसेसिस (अलगाव प्रक्रिया) के विकास पर काम किया है। इस समय इनकी रुचि के क्षेत्र में लेज़र आधारित सेपरेशन प्रोसेसिस का विकास शामिल है। ऐसी प्रक्रियाओं हेतु आवश्यक नई तकनीकों के विकास में इनका बहुत बडा योगदान है1

Dr. L.M. Gantayet

Dr. L.M.Gantayet is a Distinguished Scientist in the BTD Group of BARC. He has worked in the development of Separation Processes. His current interest includes development of Laser Based Separation Processes. He has contributed to new technologies required for such processes.

आर.एम. राव, ए.आर.परब, के.ससीभूषन तथा एस.के. अग्रवाल ने जनवरी 27-31, 2008 के दौरान अणुशक्तिनगर, मुंबई में आयोजित मॉस स्पेक्ट्रोमीटरी पर 13वीं (13वी आइएसएमएएस-डब्ल्यूएस 2008) कार्यशाला एवं सम्मेलन में डिटरमिनेशन ऑफ आइसोटोपिक कम्पोज़िशन ऑफ बोरॉन ऐज़ आरबी$_2$बीओ$_2^+$ बई टीआइ एमएस नामक शोध के लिए योगदायी शोध-पत्र के वर्ग का प्रथम पुरस्कार प्राप्त किया।

The paper entitled "Determination of Isotopic Composition of Boron as $Rb_2BO_2^+$ by TIMS" by R. M. Rao, A. R. Parab, K. Sasibhushan and S. K. Aggarwal received the 1st Prize in the Contributory Paper category during 13th ISMAS Symposium cum Workshop on Mass Spectrometry (13th ISMAS-WS 2008) held at Anushaktinagar, Mumbai during January 27-31, 2008.

एस.के.अग्रवाल, डॉ.अलमेलू , ए.आर.परब, तथा के.ससीभूषन ने जनवरी 27-31, 2008 के दौरान अणुशक्तिनगर, मुंबई में आयोजित मॉस स्पेक्ट्रोमीटरी पर 13वीं (13वी आइएसएमएएस-डब्ल्यूएस 2008) कार्यशाला एवं सम्मेलन में "स्टडीज़ ऑन दि एप्लिकेशन ऑफ इंटरनल नॉरमलैज़ेशन इन दि डिटरमिनेशन

ऑफ यूरेनियम आइसोटोप रेशियो यूज़िंग ऑक्सिजन आइसोटोपिक रेशियो" नामक शोध के लिए योगदायी शोध-पत्र के वर्ग का द्वित्तीय पुरस्कार प्राप्त किया।

The paper entitled "Studies on the Application of Internal Normalization in the Determination of Uranium Isotopic Ratio using Oxygen Isotopic Ratio" by S. K. Aggarwal, D. Alamelu, A. R. Parab and K. Sasi Bhushan received the 2nd Prize in the Contributory Paper category during the 13th ISMAS Symposium-cum-Workshop on Mass Spectrometry (13th ISMAS-WS 2008) held at Anushakti Nagar, Mumbai during January 27-31, 2008.

Ms. R.M. Rao

श्रीमती आर.एम.राव इनोरगेनिक मास स्पेक्ट्रोमीटरी एवं हाई परफोरमन्स लिक्विड क्रोमेटोग्राफी (एचपीएलसी) के क्षेत्र में कार्यरत हैं। प्रिसाइज् आइसोटोपिक अनालिसिज़ ऑफ बोरॉन बई थरमल आयोनाइज़ेशन मॉस स्पेक्ट्रोमीटरी तथा डिटरमिनेशन ऑफ अल्ट्रा - ट्रेस लेवल्स ऑफ बोरॉन बई एचपीएलसी के विकास में इनका बड़ा योगदान हैं।

Ms. R.M. Rao is working in the field of inorganic mass spectrometry and High Performance Liquid Chromatography (HPLC). Her contributions include development of methods for the precise isotopic analysis of boron by thermal ionization mass spectrometry and determination of ultra-trace levels of boron by HPLC.

श्री. ए. आर.परब इस समय भाभा परमाणु अनुसंधान केंद्र , ट्रॉम्बे, मुंबई के ईंधन रसायन विज्ञान प्रभाग के मास स्पेक्ट्रोमीटरी अनुभाग में वैज्ञानिक अधिकारी के पद पर कार्यरत्त हैं। इनकी वैज्ञानिक रुचि के क्षेत्र में "थर्मल आयोनाइज़ेशन मॉस स्पेक्ट्रोमीटरी फॉर प्रिसाइज़ आइसोटोपिक अनालिसिज ऑफ एलिमेंटस" जो कि नाभिकीय तकनीक हेतु महत्वपूर्ण हैं, भी शामिल है। इनके 60 से अधिक अनुसंधान पत्र प्रकाशित हुए हैं।

A.R. Parab

Mr. A.R. Parab is currently working as a Scientific Officer in the Mass Spectrometry Section of Fuel Chemistry Division, BARC, Trombay, Mumbai. His scientific interest is in the area of thermal ionization mass spectrometry for precise isotopic analysis of elements which are important in nuclear technology. He has more than 60 research publications in various journals and symposia.

Dr. S.K. Aggarwal

डॉ. एस.के. अग्रवाल जुलाई 2005 से भाभा परमाणु अनुसंधान केंद्र के ईंधन रसायन विज्ञान प्रभाग की अध्यक्षता कर रहे हैं तथा होमी भाभा नैशनल इन्सटिट्यूट में रसायन विज्ञान के प्रोफैसर हैं। इन्होंने वर्ष 1972 में भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र के 16वें वर्ग से स्नातकता प्राप्त करके होमी भाभा पुरस्कार प्राप्त किया। मुंबई विश्वविद्यालय से पीएच.डी की डिग्री प्राप्त करके इन्होंने वर्जीनिया विश्वविद्यालय, यू एस ए से पोस्ट - डोक्टोरल प्रशिक्षण प्राप्त किया। डॉ अग्रवाल को वर्ष 1996 में इन्डियन सोसाइटी फॉर मॉस स्पेक्ट्रोमीटरी आइएसएमएएस के द्वारा एमिनन्ट मॉस स्पेक्ट्रोमीटरिस्ट पुरस्कार से सम्मानित किया गया तथा हाल में ही इन्हें डीएई 2006 स्पेशल कंट्रिब्यूशन अवार्ड भी प्रदान किया गया। आप एटोमिक मॉस स्पेक्ट्रोमीटरी एवं अल्फा स्पेक्ट्रोमीटरी क्षेत्र के विषेशज्ञ हैं तथा विभिन्न स्पेक्ट्रोमीटरिक तकनीकों में रुचि रखते हैं। इनकी अन्य रुचियों के क्षेत्र में लेज़र बेस्ड एनालिटिकल टेक्नीक्स, इलेक्ट्रोकेमिस्ट्री, एक्सरे स्पेक्ट्रोस्कोपी एवं

सेपरेशन टेक्नीक्स जैसे सोलवंट एक्स्ट्रेक्शन आदि शामिल हैं। अंतर्राष्ट्रीय प्रसिद्ध पत्रिकाओं में आपके 100 से अधिक प्रकाशन हैं तथा मुंबई विश्वविद्यालय एवं एचबीएनआइ के मान्यता प्राप्त पीएच.डी निर्देशक भी हैं।

Dr. S.K. Aggarwal has been heading the Fuel Chemistry Division, BARC since July 2005 and is a Professor of Chemistry at the Homi Bhabha National Institute (HBNI). He joined the 16th Batch of BARC Training School in 1972 and received the Homi Bhabha Award. He did his Ph.D. from Mumbai University and did his Post-Doctoral training at the University of Virginia, USA. Dr. Aggarwal was honoured with Eminent Mass Spectrometrist Award by the Indian Society for Mass Spectrometry (ISMAS) in 1996 and was recently conferred with the DAE Special Contributions Award 2006. He is a specialist in the field of atomic mass spectrometry and alpha spectrometry and is interested in various mass spectrometric techniques. His other areas of interest include laser-based analytical techniques, Electrochemistry, X-ray spectroscopy and Separation techniques like HPLC, solvent extraction etc. He has more than 100 publications in reputed international journals and is a recognized Ph.D. guide of the Mumbai University and of HBNI.


K. Sasi Bhushan

श्री. के. ससीभूषन ने आंध्र विश्वविद्यालय से रसायन विज्ञान में बी.एससी डिग्री प्राप्त की। एक वर्ष का प्रशिक्षण समाप्त करके आपने वर्ष 2005 में भाभा परमाणु अनुसंधान केंद्र, ट्रॉम्बे, मुंबई के ईंधन रसायन विज्ञान प्रभाग के मास स्पेक्ट्रोमीटरी अनुभाग में सहायक वैज्ञानिक-बी के पद पर कार्यारंभ किया। इस समय ये आइसोटोप के विशलेषन हेतु थर्मल आयोनाइज़ेशन मॉस स्पेक्ट्रोमीटर एवं नाभिकीय पदार्थ का कंसंट्रेशन निर्धारण करने में कार्यरत हैं।

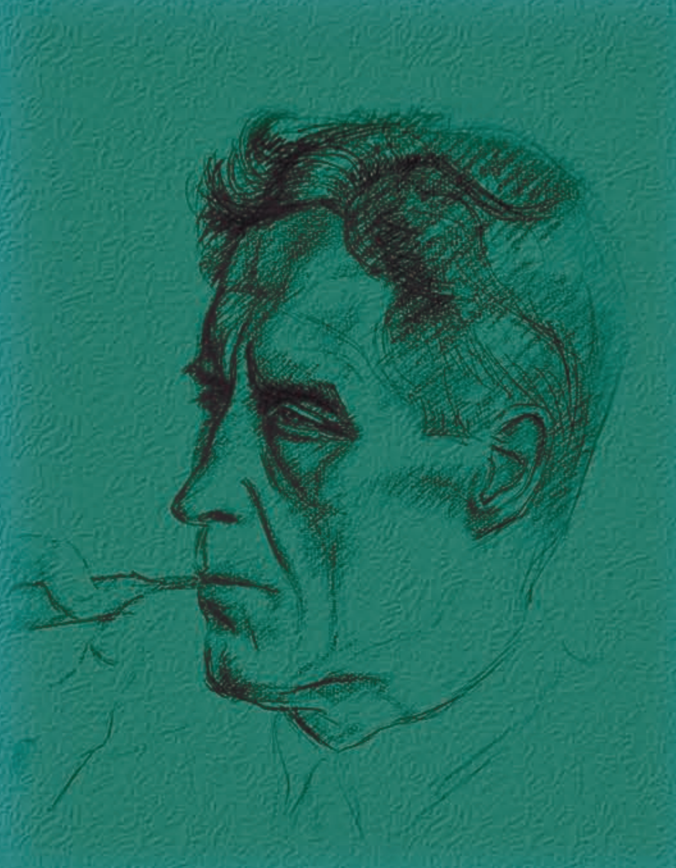
Mr. K. Sasi Bhushan obtained his B.Sc. degree in Chemistry from Andhra University. After completing one year training as Category-I trainee, he joined the Mass Spectrometry Section of the Fuel Chemistry Division, BARC, Mumbai, as a Scientific Assistant-B in 2005. He is currently working with thermal ionization mass spectrometer for isotopic analysis and concentration determination of nuclear materials.


Ms. D. Alamelu

श्रीमती डी.अलमेलू ने अन्नमलाई विश्वविद्यालय से भौतिक विज्ञान में एम.एससी की डिग्री प्राप्त की। भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण विद्यालय के 38वें वर्ग से स्नातकता प्राप्त करके आपने वर्ष 1995 में ईंधन रसायन विज्ञान प्रभाग के मास स्पेक्ट्रोमीटरी अनुभाग में कार्यारंभ किया। आप टाइम ऑफ मॉस स्पेक्ट्रोमीटर के स्थानीय विकास में व्यस्त रहीं। इनकी अन्य रुचियों के क्षेत्र में थर्मल आयोनाइज़ेशन मॉस स्पेक्ट्रोमीटरी, अल्फा स्पेक्ट्रोमीटरी तथा लेज़र इंड्यूसड ब्रेकडाउन स्पेक्ट्रोस्कोपी (एलआइबीएस) मीटरी हैं।

Ms. D. Alamelu obtained her M.Sc. Degree in Physics from Annamalai University. After graduating from the 38th Batch of Training School, BARC, she joined the Mass Spectrometry Section of the Fuel Chemistry Division in 1995. Initially, she was involved in the indigenous development of Time-of-Flight Mass Spectrometer. Her other areas of interest include thermal ionization mass spectrometry, alpha spectrometry and Laser Induced Breakdown Spectroscopy (LIBS).

P.M.S. Blackett



Portrait sketched by Dr. Homi J. Bhabha

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