



**SELINUS UNIVERSITY**  
OF SCIENCES AND LITERATURE

**QUALITY MANAGEMENT DURING IN-SITU  
RECONSTRUCTION OF FAILED SICKLE PLATES  
BY WELDING AT UNDERGROUND PENSTOCK  
OF SRISAILAM LEFT BANK HYDRO ELECTRIC  
PROJECT – A CASE STUDY**

By  
Rama Dasu Pittala

Supervised by  
Prof. Salvatore Fava Ph.D

**A DISSERTATION**

Presented to the Department of Engineering & Technology  
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**Faculty of Engineering & Technology  
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for the degree of  
Philosophy Doctor in Quality Management**

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**Declaration**

**I do Hereby attest that I am the sole author of this project/thesis and that its contents are the only the results of the readings and research I have done**

**Signature :**

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### Abstract:

In-Situ Reconstruction of failed Sickle Plates at Bifurcation Joints Nos 2 and 4 in the Penstock Piping were completed successfully in the period May-July 2013 and May-July 2014. For the first time in the world, failed Sickle Plates were reconstructed successfully in the underground Penstock at the Bifurcation Joints.

Original Sickle Plates failed in 2008 / 2009 due to various factors like Design inadequacy, Operational Imbalance, Geometric / Metallurgical Stress raisers at the inner curve of Sickle Plate, lack of side wall fusion in horizontal weld joints etc.

New Design has taken care regarding the design inadequacy. The Weld Joints orientation, Sequential and balanced Welding has ensured minimal distortion during and after welding. Deployment of in process NDT and Strict Process control during welding has resulted in defect-free weld-joints in the new Sickle Plates.

However due to differential expansion of remaining Sickle Plate at Bifurcation Joint No.2 during preheating and post heating, cracks appeared in the ferrule to Old Sickle Plate T Joints resulting in minor leakage. The leaking spots were rectified as per qualified and approved WPS.

Hence for the Sickle Plate reconstruction at Bifurcation Joint No.4, new WPS using combination of electrodes with lower preheat / post heating temperature was qualified meeting the code requirements and the New Sickle Plate was reconstructed successfully in 2014, without any incidence of cracking of Ferrule to Old Sickle Plate T joints. NDT played vital role in ensuring soundness of the structure at every stage of construction.

**Keywords:** *Sickle Plate, Bifurcation Joint, NDT Methods, Weld Sequence, Process Control, Penstock, Weld Cracks in Penstock, Combination of Welding Electrodes*

## 1. Introduction

*Penstock* comprises sluice gate to control flow of water , and a pipe / conduit to carry water to turbines.

*Bifurcation Joints* are required to divide flow in a penstock to feed multiple units.

At the bifurcations Internal *sickle plates* and external yokes are constructed to strengthen the structural members and counter the unbalanced forces created by the flow.

*Sickle Plate* is a crescent shaped rib inside the branch pipe, to give strength at the joint. The *Sickle Plate*, shaped as an internal horse-shoe girder, is also called splitter plate. It is provided at the intersection of the two branches for resistance against the forces being developed there.

Location and construction details of *Sickle Plate* are given in Figs.1&2.

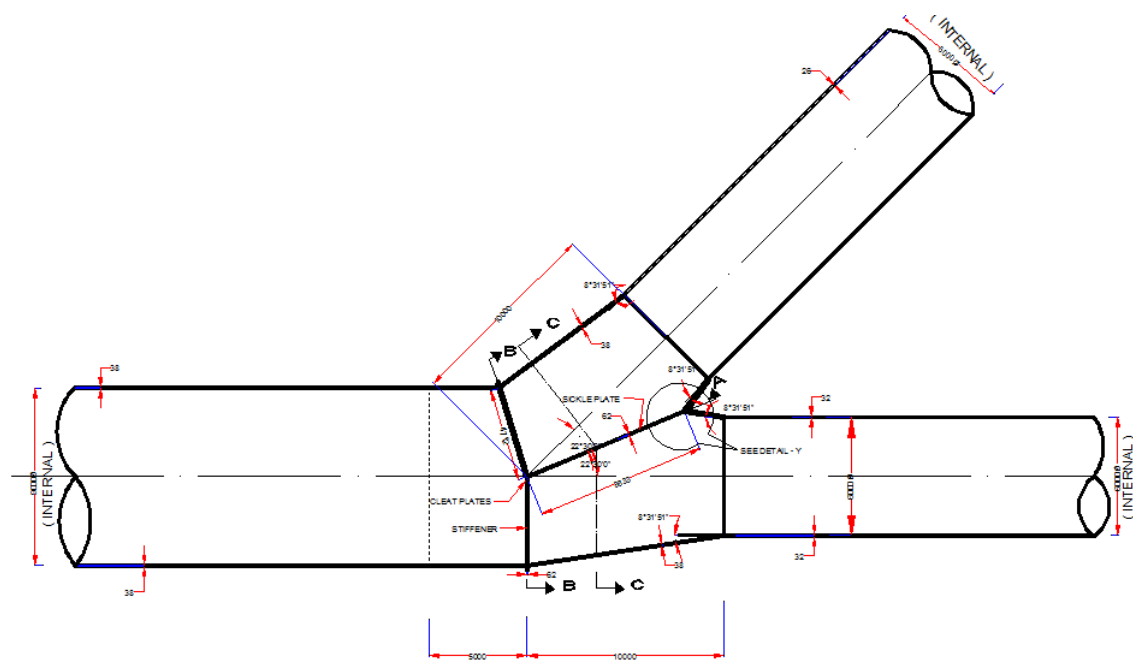


Fig.1 [2] Location & Construction details of Sickle Plate – Plan



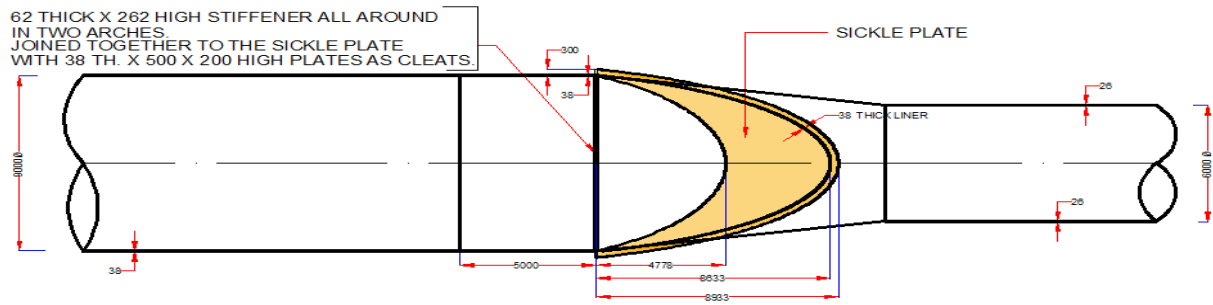


Fig.2 [2] Location & Construction details of Sickie Plate – Elevation

### 1.1 The Failure

On 11<sup>th</sup> Oct 2008 around 6.00Am, heavy vibrations were observed in Unit 2 during service. Draft tube was emptied and when examined inside, part of Sickie-plate at bifurcation between Units 2 & 3 was found stuck-up in the spiral casing of Unit 2 . ( Ref Fig.1 )

Another broken part was found in near bottom of the bifurcation joint-1. The Penstocks 4,5 & 6 were also emptied on 1.5.2009 and found 63mm Sickie Plate at Bifurcation Joint No.4 has failed. One segment of failed sickie plate was found struck up in Spiral casing of Unit-5 (but, there is no damage to runner blades) and another segment of failed sickie plate was found near MIV of Unit-6 junction. The photograph in Fig.3[1] shows that the inner curve of the Failed sickie plate was not smooth and it had geometric stress raisers which are dangerous for safety and reliability of Sickie plate's life. Earlier investigators failed to note this serious deficiency which has occurred during original construction stage.

The fracture plane observed at bifurcation Joints 2 and 4 was identical. [4]



Fig.3[1].Part of Sickle Plate found in Spiral casing of Unit 2. Geometric Stress raiser seen at the location marked with **Red Circle**.

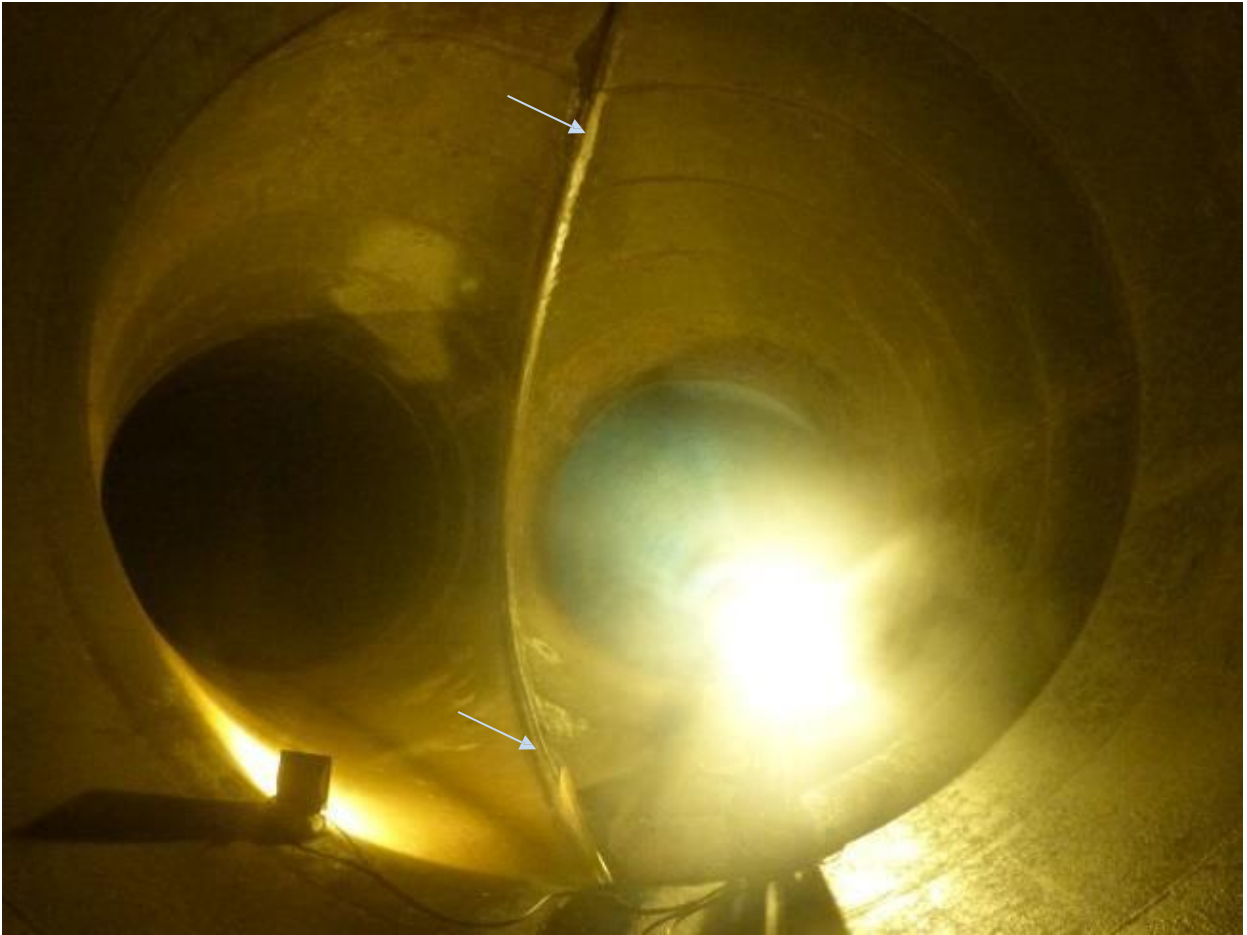


Fig.4[1] – Fig.1 - Showing Fracture plane at bifurcation between Unit 5 &6, which is very rough and un even.



Fig 5[4] Rectified fracture plane , before welding new sickle plate

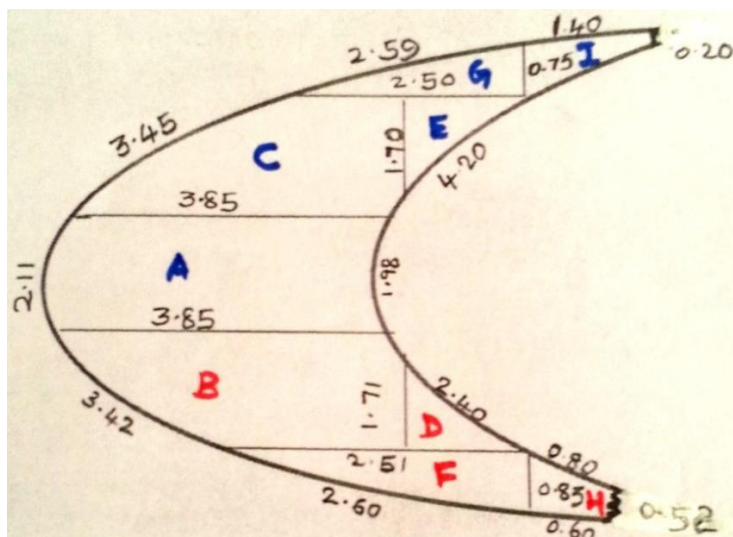


Fig.6 . Failed Sickle Plate at Bifurcation between Units 2 & 3 ( ACEGI: Found in Spiral casing of Unit 2, BDFH : Found in pressure shaft 1 sump).

APGENCO constituted expert committee comprising experts from CWC, IIT-Delhi, L&T + MWH – USA, APGENCO, NML, CEA, WRI-BHEL Trichy, FCRI-Palghat to look in the problem, examine the causes of failure of Sickle Plates and suggest remedial / rectification measures.

### 1.2 Remedial measures:

As suggested by the expert committee, the fractured surface of remaining portion of buried sickle plate was smoothed by Cutting / Grinding and weld metal deposition.

The Units 2 & 3 , 4&5 were permitted to operate in Generation mode at a capacity not exceeding 75% with a condition both the units must be in operation.

If one unit stops, the other unit also must be stopped.

### 1.3 Root cause of failure:

Design inadequacy, Operational Imbalance, Geometric / Metallurgical Stress raisers at the inner curve of Sickle Plate, presence of Lack of Side wall fusion of Longitudinal Weld etc. might have contributed for the failure. [4]

**2.0 New Design :** Based on various studies and inputs from the expert committee, M/s MWH-USA has given a new design of sickle plate . Free End patch-plates, Patch plates to join Sickle Plate to Ferrule were included in the new design to meet the design requirements.



The Author proposed location of weld joints and sequence of welding. The weld joint locations were chosen in such a way that there is minimum amount of welding and the Hot rolled plates are used in proper direction with respect to the direction of rolling.

For the patch plates there is overlap between similar welds located in the opposite faces (ref.Fig.7). The *Weld sequence* was prepared to minimize residual stresses and distortion (ref.Fig.8). [8] Weld sequence Document is given as Annexure I.

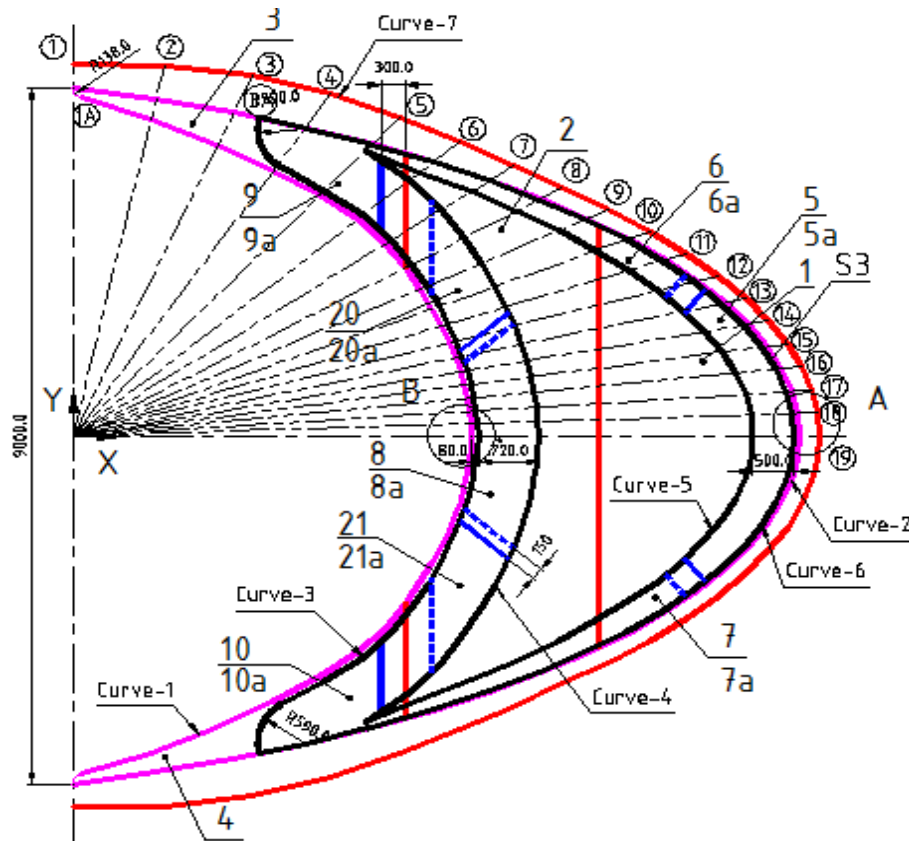


Fig.7 [3] –Location of Weld Joints, Shown in Red-Vertical and Blue

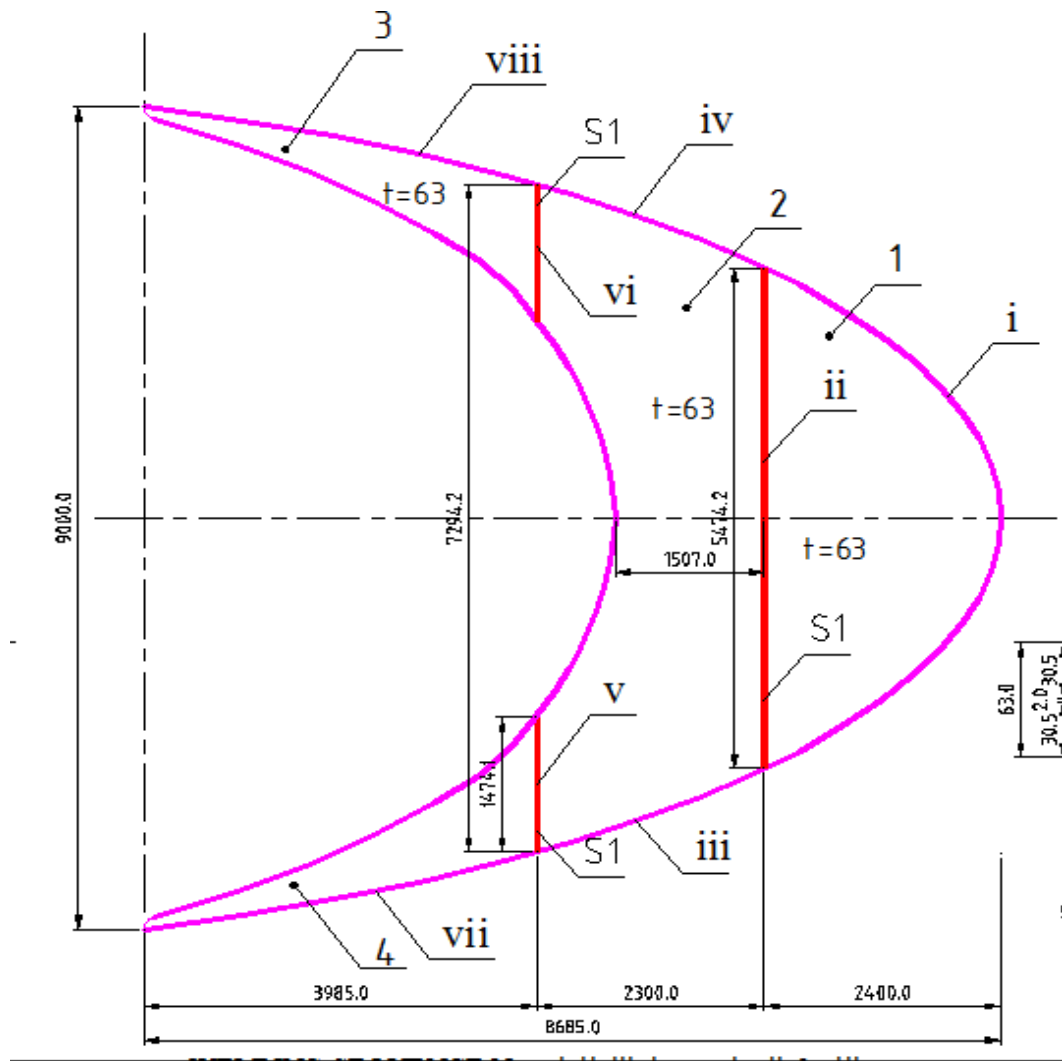


Fig.8 [3]– Weld Sequence, Shown in Roman Numerals.

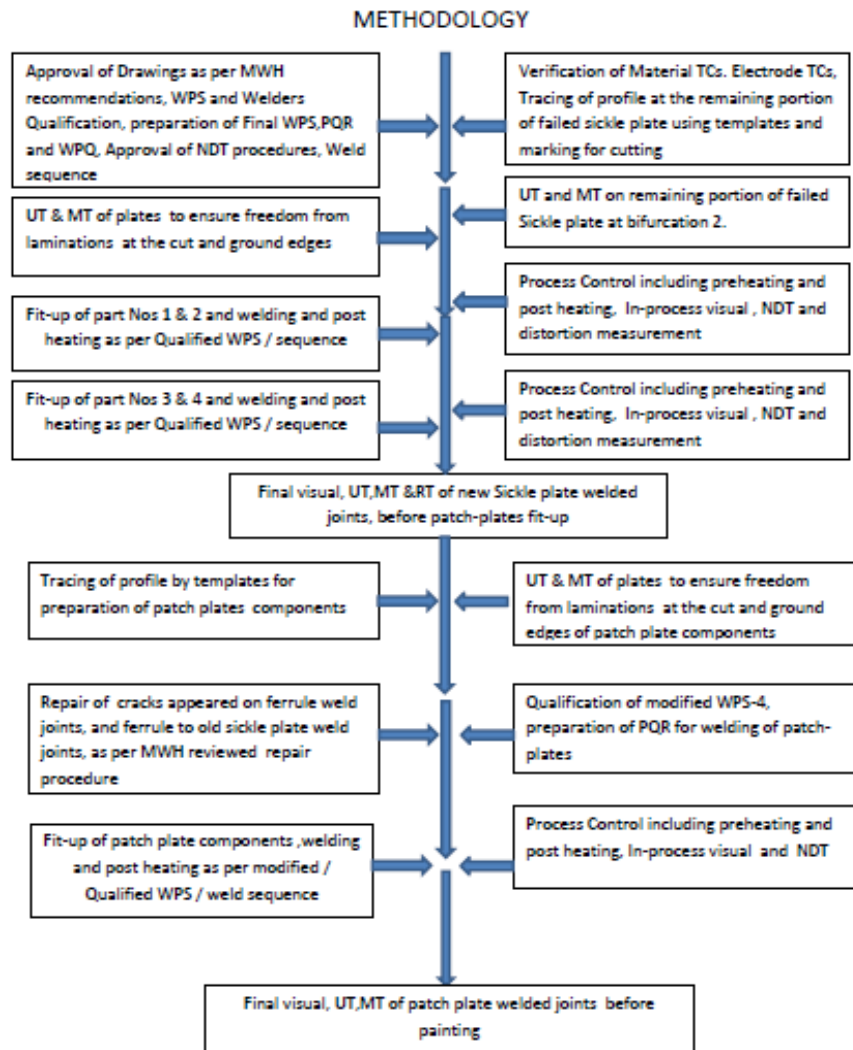


Fig.9 [3]– Detailed Methodology for Quality Management.

### 3.1 Methodology:

High Tensile Steels like ASTM A 517 Gr F have superior strength, ductility, corrosion resistance and result in economy of the project. However, these steels have lower tolerance for stress concentrations due to either geometry or weld imperfections.

In view of the above, utmost care during construction to prevent stress concentrations due to geometry and weld imperfections is required.

Accordingly detailed Methodology has been prepared and implemented to ensure that the Reconstruction of Sickle plate confirms to the Quality requirements of project technical specifications / codes ( Ref. Fig 9).

The above referred Methodology combines the Quality Assurance and Quality Control requirements in synchronization with the process flow of the Reconstruction of Sickle Plate.



***SMAW Welding Process Control:*** Welding Process was controlled and monitored by deploying Welding Inspectors on 24 X 7 basis during the project execution. Ensuring deployment of Qualified Welders for applicable Welding Position, Electrodes Control (including storage, baking, handling and usage), Preheat, Welding Current, Electrode Travel Speed, bead width, inter-pass cleaning, MT/Visual examination for each layer of welding, Post heating, Humidity data logging etc. are some of the important parameters that were monitored to ensure compliance to the approved and Qualified WPS.

**3.2 Qualification of WPS According to Project requirements:** Since the parent material is ASTM A 517 Gr F , initially WPS1 using E11018M electrodes was qualified by SMAW Welding Process.

After the completion of welding of 63mm new sickle plate at bifurcation Joint No.2, and post heating at 250°C, Minor seepage through cracks was found between ferrule to Old sickle plate T joints.

Origin of cracks might be due to embrittlement of weld-metal and stresses originated during preheating, welding, post heating and due to differential expansion / contraction of different members of the structure including ferrule.

These cracks were repaired before welding patch plates. Patch plates to sickle plate were welded without any event by following WPS2, E7018 electrodes for root& filling, followed by E11018M electrodes for capping, by SMAW Welding Process.

The maximum inter-pass / post heating temperature followed for WPS 2 was 180 °C. The bifurcation joints are located under a hillock, and a minimum water head of 132M is present in the reservoir. Hence prevention of cracking of old sickle plate to ferrule joints for Bifurcation joint No.4 was planned by choosing a WPS which needed less inter-pass and post heating temperature of 180°C.

WPS3 using E9018M electrodes for the root &filling, E11018M electrodes for capping by SMAW welding Process was qualified and successfully followed for welding the new 63mm sickle plate at bifurcation Joint No.4 .

For welding of patch plates of sickle plate at this location, WPS4 using E8018C3 electrodes for root& filling, E11018M electrodes for capping by SMAW Welding Process was qualified and successfully followed.

Without compromising design requirements of weld strength, combination of electrodes have been used successfully in this project. Transverse weld tensile test results are presented in table. 10.

WPS No.	Electrodes used For root & filling/ capping	Transverse Tensile strength of weld samples ( 4 Nos) in N/mm <sup>2</sup>			
01	E11018M/ E11018M	798.98	860.94	832.31	852.13
02	E7018/ E11018M	605.39	615.71	623.55	626.10
03	E9018M/ E11018M	818.14	836.34	834.12	847.16
04	E8018C3/ E11018M	738.13	755.85	740.18	730.14

Table 10. Transverse weld tensile test data for various combination of Welding electrodes.

Detailed description and experimental results for the Qualification of new WPS for construction of failed Sickle Plate at bifurcation No.4 at Srisailam Left Bank HEP is given below.

## 3.2 Qualification of New WPS for Sickle Plate Reconstruction at Bifurcation Joint No.4 (between Units 5&6)-SLBHES-Srisailam

### 3.2.1 Introduction :

During reconstruction of 63mm Sickle plate at Bifurcation No.2 ( Between Units 2 &3) cracks were found in the weld joint between remaining old sickle plate and ferrule, and also in weld metal of ferrule to ferrule near T joints by Magnetic Particle Testing. Apparently these cracks appeared due to differential expansion of remaining old sickle plate and ferrule during preheating / post heating. There was an elevation difference of about 60 to 70mm at this location between Unit 2 and Unit 3 sides. It is seen that all the defects found were located in welds which were made in overhead position.

Considering the above , during Expert committee meeting dated 29<sup>th</sup> July 2013, it was proposed by the author that K-Joint may be welded using a lower strength / high toughness welding electrodes ( E8018-C3 / E9018M for root and filling followed by E11018M for capping) after satisfactory Procedure Qualification as per ASME Sec IX . M/s MWH has expressed opinion that if the WPS Qualifies as per ASME Sec IX, then they may review the records and approve the new WPS/PQR . Hence new WPS has been prepared and test coupons welded and tested . Details are given below.

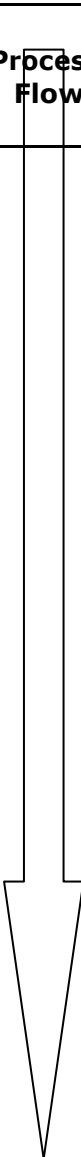
**3.2.2 New WPS :** Two WPS were prepared as per details given below.

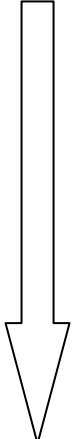
- 1) WPS No.PES/SLBHES/E8018C3-11018M/2013-14 Rev0 for the combination E8018-C3 for root and filling followed by E11018M for capping
- 2) WPS No.PES/SLBHES/E9018M-11018M/2013-14 Rev0 for the combination E9018M for root and filling followed by E11018M for capping.

Process followed for preparing the Weld Test coupons and photographs taken are given in pages 3 to 5.

Temperature Vs Time Log in Graphical form presented in Annexure -1 for the Test coupons.

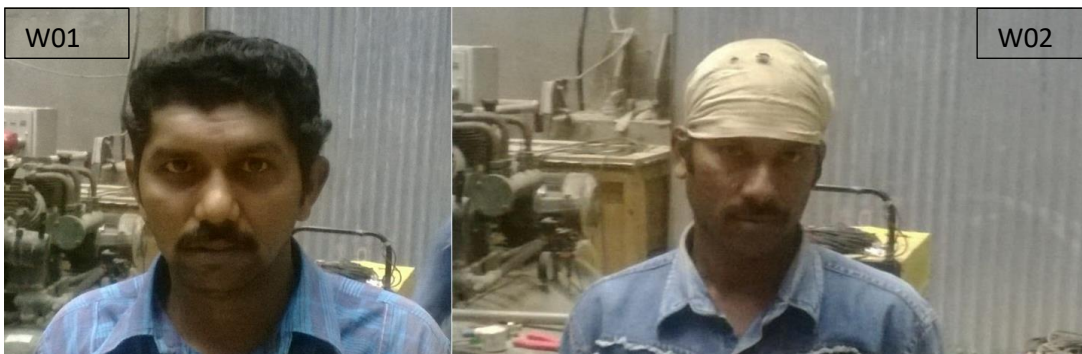
### 3.2.3 Process Flow Chart

<b>PROCESS FLOW CHART (For WPS Test Coupon welding)</b>			
SL.No.	Description	Process Flow	Activity Carried out
1	TEST COUPON MATERIAL RECEIPT		Checked Visually for rust and for any surface defects
2	TEST COUPON PREPARATION		Ground the surface and ensured Visually no surface defects.
3	TEST COUPON INSPECTION		Dimensional, Visual Inspection carried out - Found Satisfactory.
4	ATTACHING RUN IN AND RUN OUT PLATES TO TEST COUPON		Tack welded run in & run out plates to test coupons.
5	TEST COUPON FIT UP		Fit up completed by using two "C" clamps at back side
6	FIT UP INSPECTION		Inspected and found satisfactory.
7	TEST COUPONS POSITIONED FOR WELDING		Coupons were positioned as convenient to welder in a 3G position.
8	ARRANGEMENT OF HEATING COILS		Arranged heating coils at the opposite side of welding.
9	PRE HEATING TEST COUPON		Ensured Pre Heating Temp as per PWPS.
10	ELECTRODE REBAKING		Done Electrode Re-baking as per supplier recommendation.
11	ELECTRODE TRANSFERING IN TO PORTABLE CARRYING OVENS (QUIVERS)		Transferred in to Quivers and maintained temperature at 120°C.
12	ROOT WELDING		Root welding carried out as per respective PWPS .

13	FILLING		Filling welding completed as per respective PWPS.
14	BACK GRINDING		Removed heating coils, "C" Clamps, kept both at the other side and ensured inter pass temperature as per PWPS and completed back grinding.
15	INSPECTION AFTER BACK GRINDING		Visual Inspected after back grinding and released for welding.
<b>Process Flow Summary</b>			
SL. No.	Process Name	Process Flow	Activity Done
16	COIL REMOVAL, REARRANGEMENT AT OTHER SIDE AND "C" CLAMPS REMOVAL.		"C" clamps removed and rearranged coil at other side.
17	OTHER SIDE WELDING		Other side welding completed up to final as per respective PWPS
18	POST HEATING		Post heating carried out for 2 hours at 180←C
19	COLLING AFTER POST HEATING		After 2 hours of post heating soaking time, power supply to coils was terminated . Cooling rate recorded. Heating coils were removed next day.
20	VISUAL INSPECTION, BALANCE TESTS		Final visual inspection carried out, identification marking completed and arranged for NDT and mechanical testing after 72 Hrs.



Test coupons fitment, root-gap inspection



W01- Mr. Kishore , Welded With E 8018 C3 & E 11018 M Electrodes in 3G Position.

W02- Mr. Trimurthulu , Welded With E 9018M & E 11018 M Electrodes in 3G Position



Inter-pass cleaning of  
Test coupons.



← Welding Under progress.



Ovens used for Electrodes Baking



- 1- After completing welding of one side with electrodes E 8018 C3 & E 11018 M
- 2- After completing welding at one side of test coupon with electrodes E 9018M & 11018 M

### 3.2.4 Testing of Welded Coupons :

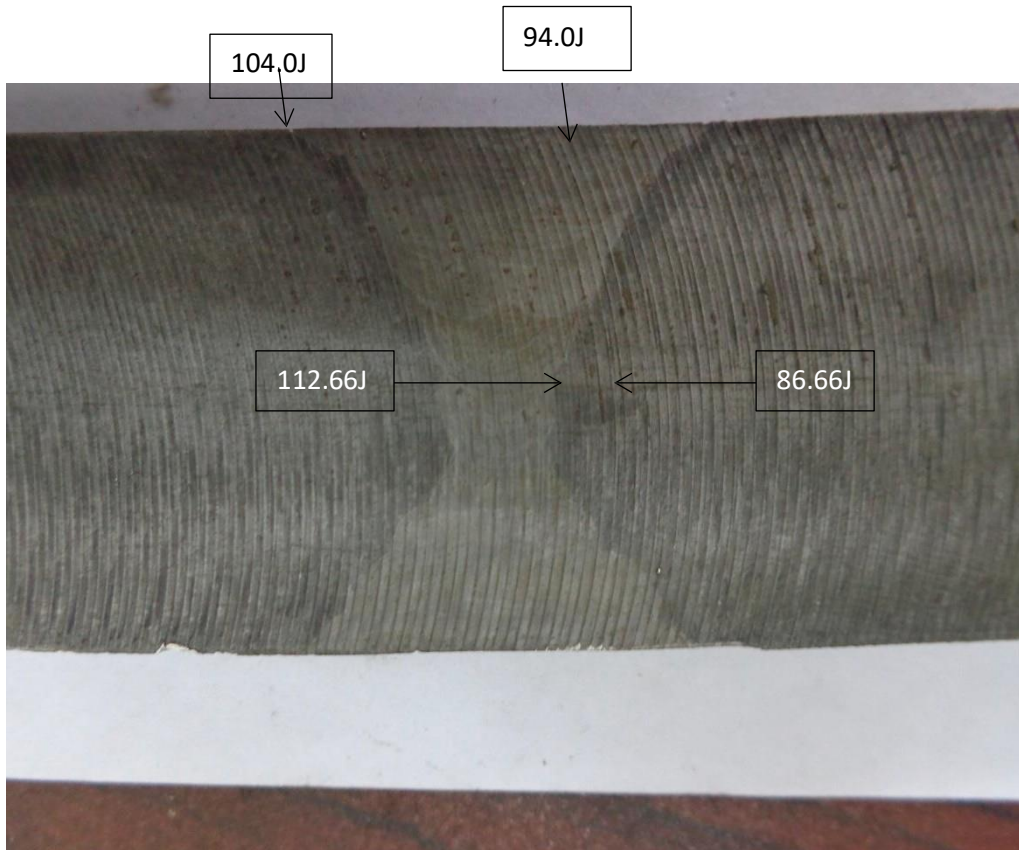
Radiography, Transverse Tensile, Side bend, Charpy V Notch impact testing at  $-29^{\circ}\text{C}$ , Macro etching, Hardness tests etc. were conducted as per requirements of ASME Section IX . Radiography found to be satisfactory for the two test coupons.

### 3.2.5 Results of Mechanical Testing:

1-A) For test coupon welded as per WPS No.PES/SLBHES/E8018C3-11018M/2013-14 Rev0 using the combination E8018-C3 for root and filling followed by E11018M for capping, results of mechanical are as follows.

	Transverse Tensile Properties			Charpy Impact Strength in J, tested at $-29^{\circ}\text{C}$ ( lateral exp. in mm),27min			Remarks
	* YS in N/mm <sup>2</sup>	UTS in N/mm <sup>2</sup>	* % El	HAZ	Weld	Location of sample	
T1A	718.43	738.13 $\sigma$	17.2	104 (1.0), 114 (0.9), 94(0.9); Av: 104 110 (1.3), 66 (0.7), 84(0.8), Av:86.66	82 (0.9), 104 (1.0), 96(0.9) Av: 94 148 (1.4), 76 (0.6), 114(1.0) Av:112.6 ;	Outer fibre	1) *YS and %El are for information only. 2) 4 Nos Side Bend test – satisfactory. 3) $\sigma$ UTS is 91.84-95.08% of minimum UTS of ASTM 517 Gr F requirement (795- 930 N/mm <sup>2</sup> )
T1B	725.59	755.85 $\sigma$	20.0				
T2A	690.25	740.18 $\sigma$	19.0			Core	
T2B	702.80	730.14 $\sigma$	17.8				





**Charpy V notch location and Average impact strength**

#### 1B) Hardness Test Results

Outer Fibre:      1) Parent metal-      29,30,30 HRC / 294,302,302 HV  
                          2) in weld-                      29,29,29 HRC/ 294,294,294 HV  
                          3) Heat affected zone- 28,29,28 HRC/ 286,294,286 HV

CORE            :      1) Parent metal-      29,30,30 HRC / 294,302,302 HV  
                          2) in weld -                      23,22,22 HRC/ 254,248,248 HV  
                          3) Heat affected zone- 27,27,27 HRC/ 272,272,272 HV

2A) For test coupon welded as per WPS No. PES/SLBHES/E9018M-11018M/2013-14 Rev0 using the combination E9018M for root and filling followed by E11018M for capping, results of mechanical are as follows.



	Transverse Tensile Properties			Charpy Impact Strength in J, tested at -29°C ( lateral exp. in mm) 27 min			Remarks
	*YS in N/mm <sup>2</sup>	UTS in N/mm <sup>2</sup>	*% El	HAZ	Weld	Location of sample	
T1A	745.91	818.14	20.8	162 (1.4), 176 (1.5), 180(1.6) Av:172.66 140 (1.4), 188 (1.5), 194(1.6) Av:174.00	44 (0.6), 46 (0.6), 36(0.5) Av:42.00 50 (0.7), 72 (0.8), 48(0.6) Av:56.66	Outer fibre	1) *YS and %El are for information only. 2) 4 Nos Side Bend test – satisfactory. 3) UTS is meeting the requirement of ASTM 517 Gr F (795- 930 N/mm <sup>2</sup> )
T1B	802.94	836.34	22.0				
T2A	784.26	834.12	19.2			Core	
T2B	791.20	847.16	19.6				



**Charpy V notch location and Average impact strength**

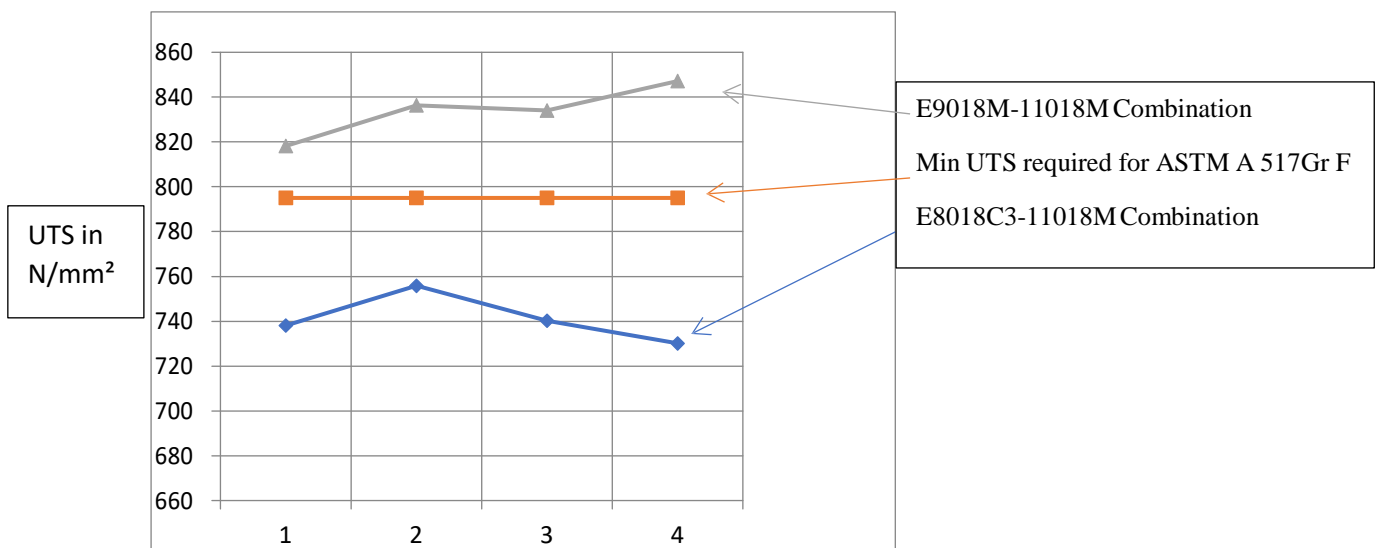
## 2B) Hardness test results:

Outer Fibre:      1) Parent metal-      29,30,30 HRC / 294,302,302 HV

	2) in weld -	30,30,29 HRC/ 302,302,294 HV
	3) Heat affected zone-	26,26,26 HRC/ 272,272,272 HV
CORE:	1) Parent metal-	28,29,29 HRC / 286,294,294 HV
	2) in weld -	29,29,29 HRC/ 294,294,294 HV
	3) Heat affected zone-	28,27,28 HRC/ 286,272,286 HV

### 3.2.6 Discussion :

- All the properties including transverse UTS is meeting the requirement of ASTM A 517 Gr F material for the WPS No.PES/SLBHES/E9018M-11018M/2013-14 Rev0 in which the combination of electrodes E9018M for root and filling followed by E11018M for capping were used.
- In case of WPS No.PES/SLBHES/E8018C3-11018M/2013-14 Rev0 using the combination E8018-C3 for root and filling followed by E11018M for capping, the transverse UTS was found to be about 92-95% of the minimum UTS required for ASTM A 517 Gr F material.



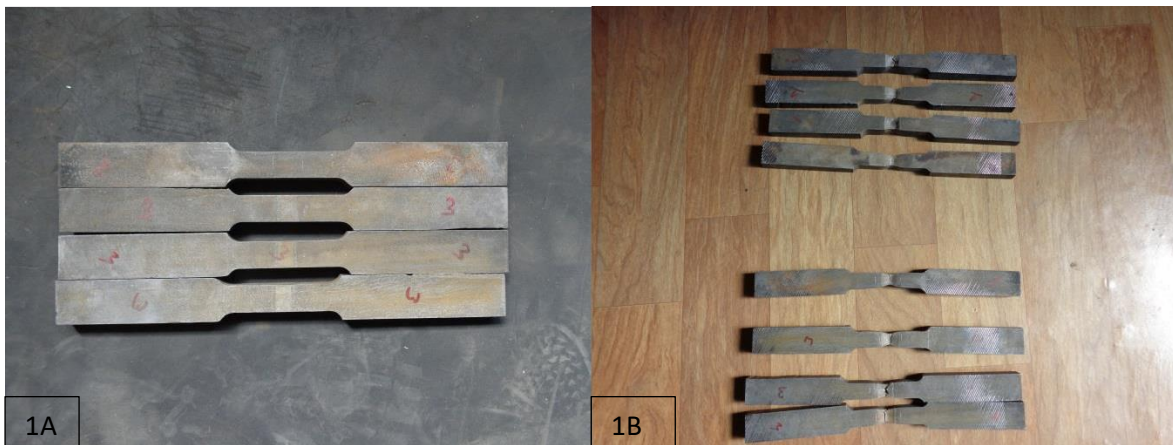
### 3.2.7 Observations:

**3.2.7.1** WPS No.PES/SLBHES/E9018M-11018M/2013-14 Rev0 is qualified as per ASME Section IX for use in reconstruction of 63mm Sickle Plate at Bifurcation Joint No.4, (between Units 5 & 6). PQR No. PES/SLBHES/E 9018M-11018M/2013-14 dated 11.12.13 is attached for reference. This shall be used for welding Vertical Joints and Circular Joint of Sickle Plate and also for welding free end patch plates.

**3.2.7.2** It is proposed to use WPS No.PES/SLBHES/E8018C3-11018M/2013-14 Rev0 for welding of Patch plates to ferrule fillet joints / other highly strained joints, not covered by the above referred WPS.

3.2.7.3 It is common Industry practice to use low strength Electrodes for Highly Restrained Weld Joints, to prevent cracking / High Residual Stresses in high temperature / humid conditions, provided it meets other design requirements. For Example at Hongawa Power plant – Japan, Soft Joints using 600MPa Class Welding Consumables were used to weld HT 780 material of Penstock to reduce cold cracking in High Temperature /Humid Conditions.

## 6.0 Photographs taken during testing of samples



1A & 1B - Tensile Samples , before testing, and after testing. Ductile Fracture in weld can be seen.



2A – Charpy V Notch Impact samples before testing, 2B – Samples soaked in bath at  $-29^{\circ}\text{C}$  before testing.





3 A



3B



3C



3 D



3E



3F

3A to 3F – Side Bend Testing



4A- Side bend tested sample



4B- Hardness tested sample after macro etch



5A – Macro-etched weld sample

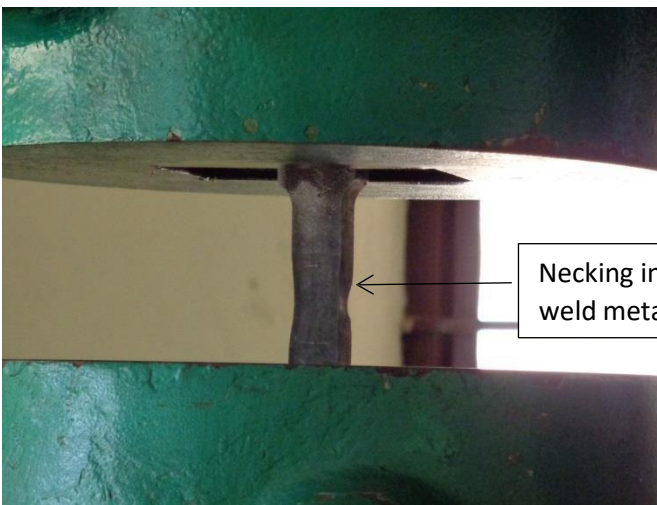


5B- Side bend tested after macro etching





6A



6B



6C



6D

6A to 6D- Transverse tensile testing .

#### 4.1 NDT Scheme followed & Findings :

1) Prior to welding, MT & UT of remaining portion of sickle plate and weld joints performed as per approved NDT procedures.(ref. Figs .10 & 11).

For MT wet visible particles with white contrast were used in combination with Half-wave DC Yoke. For UT, 4MHz 20 Dia TR probe, 4 MHz 45° 8X9 size, and 4 MHz 60° 8X9 size probes were used. Calibration blocks used for UT was made as per ASME Sec V Article 4, Fig.T-434.2.1 Non Piping Calibration Block.

The findings indicated that there are no un-acceptable flaws in case of Bifurcation Joint No.2.

Incase of Bifurcation Joint No.4, 9 Nos of transverse cracks were found.





Fig.11A- Transverse cracks found during MT of Remaining Sickle Plate .



Fig.11B- Appearance of Transverse crack after grinding 8mm deep.

In addition to the transverse cracks, lamination of about 500mm long was found during ultrasonic examination of remaining sickle plate portion at overhead position, Chainage 18.5 to 19.0 at bifurcation joint No.4.



11C- Lamination found in UT at Chainage 18.5 – 19.0.

During UT of remaining sickle plate at Bifurcation joint No4, isolated point indications within acceptable limit were seen at a depth between 10 to 30mm from the flat surface of the built up layer .

In view of these indications, the MT was repeated after preheating as well. Between Chainage 9.5 to 10.5 many transverse cracks appeared after preheating.



11D-same location after grinding to remove lamination

All such cracks were removed by grinding up to sound metal and repeat MT using dry particles carried out. (Refer Fig 12.A). This has resulted in improper root gap and irregular surface of K joint profile. This location has been weld repaired and proper root gap ensured prior to commencement of Part 1 welding.( Ref. Fig 12.B ).





Fig.12A-Transverse cracks removed by grinding., resulting in uneven root gap.



12B- Weld repaired to ensure proper root gap.

- 1) The Hot rolled plates of ASTM 517 Gr F material was tested ultrasonically using 6mm FBH reflector for calibration, and 4MHz 25mm dia probe for scanning, to ensure the absence of laminations near cutting plate. .
- 2) During welding after each layer and back grinding also MT was performed using Dry Visible Particles in combination with Half-wave DC Yoke. Relevant Indications were removed by grinding.
- 3) After 72 Hrs of completion of welding and post heating, final NDT (VT,MT UT &RT) performed on new sickle plate weld joints. For MT wet visible particles with white contrast were used in combination with Half-wave DC Yoke.

For UT, 4MHz 20 Dia TR probe, 4 MHz 45° 8X9 size, and 4 MHz 60° 8X9 size probes were used. Calibration blocks used for UT was made as per ASME Sec V Article 4, Fig.T-434.2.1. Radiography performed using Ir 192 source with single wall single image composite film viewing technique.

At bifurcation Joint No.2, one un-acceptable linear indication of about 30mm long was found in Vertical weld ii at around 550mm from bottom. The same was repaired, retested by MT, UT and RT to ensure soundness of the weld. In case of new sickle plate at Bifurcation Joint No.4, no un acceptable flaws were found by MT,UT and RT.

- 4) During MT, cracks were found in the weld-metal of T joints of Ferrule to Old Sickle plate, which were repaired and retested. The cracks had zig-zag pattern indicating embrittlement of weld-metal.  
The weld-metal and parent metal adjacent to the remaining sickle plate was subjected to repeated heating cycles thrice..
- 5) Subsequently Welding of Free End patch plates and Sickle plate to Ferrule patch plates carried out as per approved and qualified WPS. In process MT carried out as indicated in Point-1 and ensured soundness of each layer.
- 6) After 72 Hrs of completion of welding and post heating, final NDT(VT,MT&PT) performed on the new sickle plate to patch-plate weld joints.

No flaws were found. Weld Visual Test confirmed that the weld profile / size is satisfactory.

**5.0 Conclusions:** Project specific QA/QC methodology considering requirements and the challenges involved has been implemented for in “ In-Situ Reconstruction of failed Sickle Plates by Welding at underground Penstock of Srisaïlam Left Bank Hydro Electric Project. Special Weld procedure Qualification using combination of welding electrodes was carried out and the same was implemented successfully through strict Process control during welding, applying right NDT methods to ensure quality and a good team work are some of the important factors that are responsible for the successful reconstruction of failed sickle plates for the first time in the world. The Units have been put in to service at 100% of the rated capacity and during the 2014 season the Power Plant has generated record output since its commissioning.

**6.0 Recommendations:** Balanced operation of Units and Periodical Condition assessment during off season has been recommended to maintain the structural integrity of the new sickle plates.