Developing Quality Assurance Programmes for Welding applications in Indian Projects

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1. Introduction

1.1. Welding is the technological process of joining two materials, mainly metals and alloys in different forms. All types of industrial developments, ranging from electronic industry to heavy engineering industry, have benefitted from the advances made in welding technology. As the welding process acquires greater role in the total production process, the quality of welding achieved during the production operation also emerges as a serious and relevant factor. Several techniques of testing welding joints, both as checks during welding process and as non-destructive tests on completion of welding, have been developed to assess the quality of welding. As in other fields of production operations, concepts for ensuring quality of operations through a planned system of Quality Management have become relevant for welding applications. Advanced technological industries like fertilizers and chemical, petrochemical and petroleum refining plants, electrical power generating plants, etc. have recognized the need for a system of Quality Assurance for achieving overall plant performance of a high order. In this background, it is relevant to examine the status of Quality Assurance systems in welding applications in Indian Industries so as to recognize corresponding application in chemical and process industries.

1.2. Quality Assurance is a system of planned practices that ensures the integrity of a structure, component or assembly of an industrial plant and ensures reliable short term and long term performance. The emphasis here is on developing a system of pre-planned activities. In other words, the quality of any operation does not result by chance or by accident but it is achieved and ensured through a system of pre-planned activities.

1.3. Planning for achievement of quality must necessarily encompass all activities leading to the commissioning and operation of industrial plants. It will cover :

1. Research and Product Development
2. Technology and Process Development
3. Materials
4. Design and Engineering
5. Production of components and equipments
6. Erection and Commissioning
7. Operation

A planned system of Quality Assurance in welding as applied to any industry must, therefore, span all the activities mentioned above. Different industries may require different levels of emphasis and attention to different functional areas from among those listed above. Critical plants or systems handling hazardous chemicals or equipment working in special environmental conditions will demand additional or unique criteria to govern the Quality Assurance system. There can, therefore, be no single code of practice that can apply to all industrial situations. Instead, Quality Assurance systems must be specifically tailored for each industry though these systems will be based on sound concepts or criteria that are applicable in common to different industrial situations.

1.4. These general principles governing the planning for achievement of Quality equally apply

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to welding, as a technological component to an industrial plant. This paper will outline the developments that are being spearheaded in electrical power generating plants so that similar activities can be initiated actively in the chemical and process plant industries which also serve electrical power projects.

1.5. The presentation in this paper will be limited to outlining the principal action stages in evolving a Quality Assurance system for an operational industry.

2. Planning for Quality Assurance

2.1. Quality Engineering

2.1.1. As pointed out earlier, Quality Assurance is a system-oriented activity and comprises of several pre-planned activities in all the functional areas. The start of any production operation in a chemical or process plant industry is Engineering which prepares and issues Specifications and Drawings. In relation to welding, these Specifications and Drawings must, therefore, be specific and clear in bringing out the design intent so that production operations will satisfy the design requirements in due course. Lack of clarity or lack of details can often lead to deficiencies during production. The significance of these remarks will be recognized if it is realised that design engineers in several chemical or process plant industries may be more proficient in the design and engineering of the concerned process technology rather than in the relevant welding technology. Under these circumstances, recourse is often taken to delegate detailing of welding specification requirements to either the shop floor level or to subordinate and ill-informed technical personnel in the design department or in generalized terms to standard code requirements without identifying specific applicable details. In a review of design practices related to welding operations on a major product being regularly manufactured by a large production organisation, the following types of deficiencies have been detected :

1. Inadequate welding symbols and non-conformity to standard symbols.
2. Lack of clear detailing of welding joints.
3. Poor appreciation by designer of changes in edge preparation on contoured fit-ups and absence of good design in detailing junctions of different plate sections.
4. Absence of plate cut-out drawings with flame-cutting dimensions properly related to good fit-up during assembly.
5. Bad welding joint designs which prevent good fit-up, deny access to electrodes for defect-free bead deposition, obstruct application of proper NDT techniques, etc. See Fig. 1 & 2
6. Inability of designers to furnish essential welding instructions in the drawings to indicate or supplement standard welding technology procedures or instructions.
7. Poor choice of testing and inspection requirements, particularly in the selection of NDT techniques.

2.1.2. The review, as above, has brought home the essential point that defect-free welding in the shop-floor calls for adequate quality standards to be maintained in the designs, drawings and specifications for weld joints. Taking the same product as an example, the following programme has been formulated to develop a sound quality engineering system for welding application as related to this product :

1. A specially formulated training programme to brief the design engineers with additional welding technology information as relevant for good design of weldments.

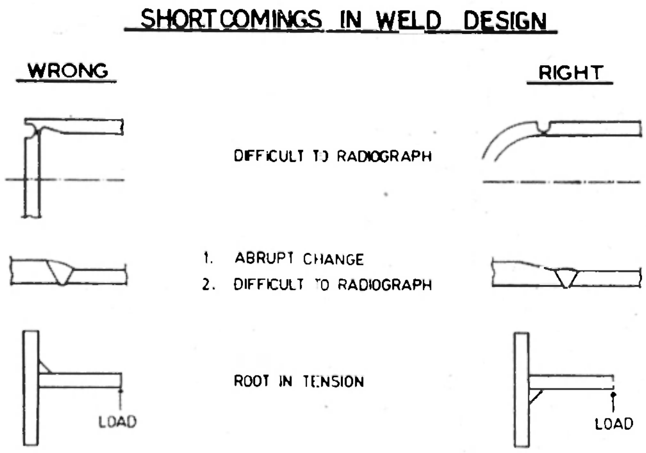


Fig. 1

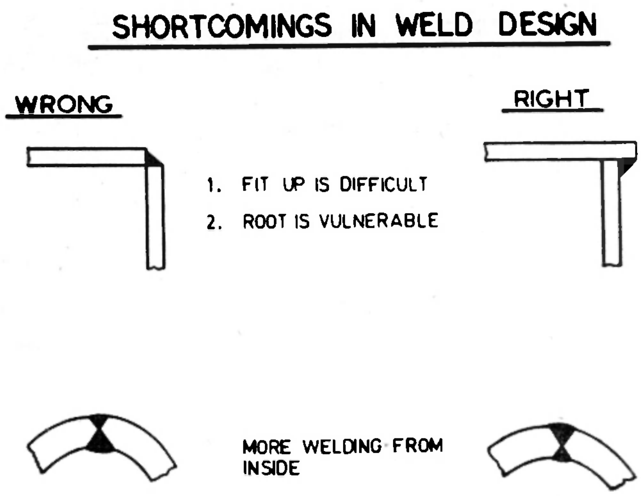


Fig. 2

2. An expert and detailed review of designs and drawings prepared earlier by the design team and identifying specific points for change and modification.
3. Preparation of a designer's guidance manual for ensuring proper designs for future engineering.
4. A written-down system of drawing review to check for errors, to ensure conformity to required standards of detailing, to allow for prior review and consultation with Welding Technology and Production personnel.
5. A system of Quality documentation for feed-back of shop-floor production information on actual welding to enable designers to get an assurance regarding adequacy of design and engineering detailing for achieving the required quality of welding and to serve as additional developmental information for guidance of engineers for future work. (Fig. 3)
6. A system of Quality Engineering Audit that will periodically highlight the current status of Quality Engineering practice.

2.2. Quality of Materials

Plant and Equipment installed in modern industries require use of raw materials and consumables conforming to the required specifications. It is, therefore, necessary to operate a Materials Management system that will ensure :

1. Procurement of required materials and consumables from reliable vendors of proven quality performance.

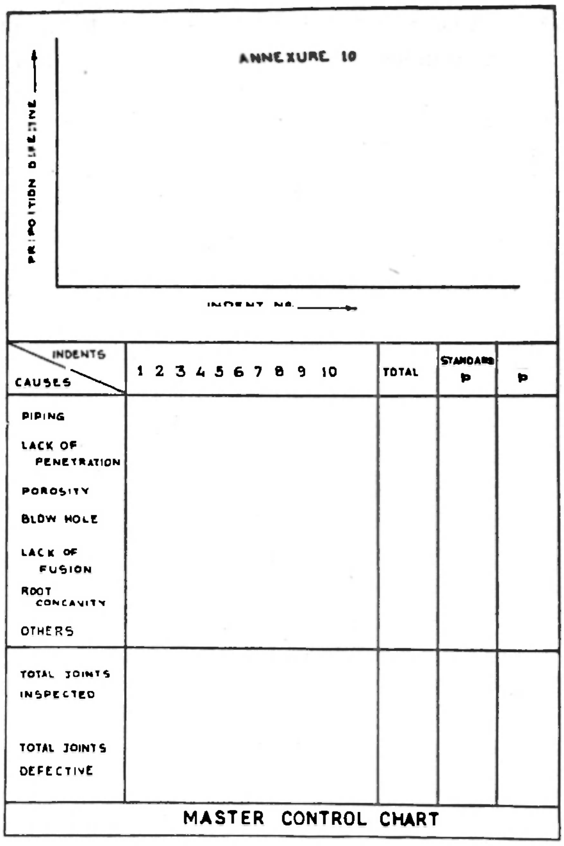


Fig. 3

2. System of documented certification for proven conformity of materials supplied to the specifications and a system of identification of materials by proper correlation to certificates.
3. Proper system of storage so that material identity will not be lost and deterioration of material will not take place.
4. Proper handling during unloading and loading operations during different stages of production.
5. Proper retrieval of balance material and segregation of waste material to prevent misuse and improper application.
6. Periodic Audit to report on the Quality Status of the total Materials Management System.

2.3. Quality of Production Operations.

2.3.1. Different production organisations have different standard practices to control the various functions of production operations. It will be worthwhile to review these details to assess the quality status and to identify areas of weaknesses which lead to quality deficiencies.

2.3.2. A case study undertaken in one of the major manufacturing facilities will illustrate the methodology that can be adopted for such a review.

2.3.2.1. Different types of heaters are installed in the heat regenerative system of a thermal power plant and one type of such heaters employs spiral coil design. (Fig. 4) The quality of weld joints in heaters of spiral coil design determines their reliable functioning in the heat regenerative system. In this study, an attempt has been made to identify the quality status of one type of welding joint and the factors responsible for the present level of rework in TIG/Gas Welding and to suggest measures to bring down the rejections and rework. The study was conducted on the spiral coils of heat exchangers used for two different unit sizes of thermal power plants, designated as unit size A and B. The details are given in the Table 1.

A single spiral coil is a long seamless tube formed into the shape of spiral. A twin spiral is formed by welding two single spirals by a butt joint between spiral tube to spiral tube. Two stubs at the two ends of the twin spirals of Unit Size A and B are butt welded.

2.3.2.2. An analysis of past data covering a period of 4-1/2 months was undertaken as explained below :

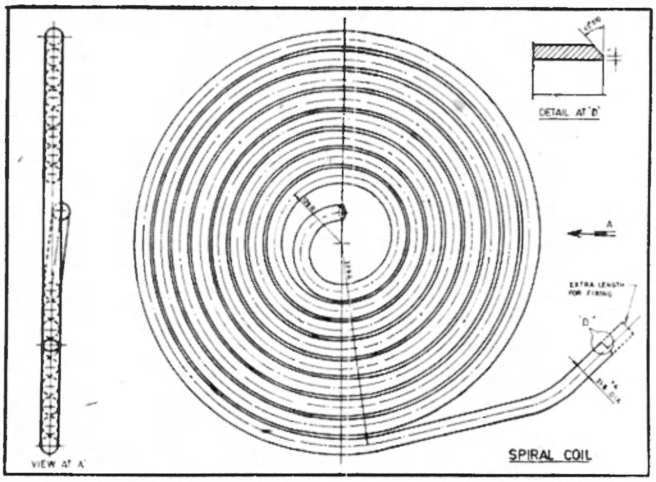


Fig. 4

Class-wise Analysis

Table 2 gives the percentage of defective spirals in the two different unit sizes. Here a defective spiral is that which has one or more defective weld joints.

It is clear from the above table that the percentage of defective joints is much higher in Unit Size A as compared to Size B and so further study was restricted to the Unit Size A only.

For Unit Size A, a month-wise break-up of the defective joints produced reveals that, in general, TIG welded joints have higher percentage of defectives as compared to gas welded joints. This situation is contrary to the normal technological expectation since TIG welding is potentially capable of producing

Table 1 Details of Spiral Coils

Unit Size	No. of Heaters	No. of spirals	Material of spirals	No. of Weld Joints			
				Spiral to Spiral	Spiral to Stub	Total	
Size A	3	1556	Carbon Steel ST 45	778	1556	2334	2610
		184	13 Cr. Mo 44	92	184	276	
Size B	2	960	Carbon Steel ST 35	480	960	1440	

Table 2 Percentage of Defective Spirals as per Radiography Report

S.No.	Unit Size	Process	Total Number of Spirals		% Defective
			Inspected	Defective	
1.	Size A	TIG & Gas	1098	420	41.0%
2.	Size B	Gas	360	25	6.9%

superior quality of joints as compared to gas welding. The problem can, therefore, be related to some deficiency in either the TIG welding process as practiced in the shop-floor or with the welder's skill.

The X-ray reports of defective joints were scanned to identify the major types of welding defects. The analysis of the defects indicated that more than one type of defect could occur in a particular joint. It was seen that about 90% of the defects in TIG welded joints were contributed by the following types of defects :

1. Piping 41.5%
2. Lack of penetration 17.9%
3. Lack of fusion 17.5%
4. Porosity 15.7%

Position-wise Analysis

At present, welding of a butt-welded joint is carried out in vertical, overhead and down-hand positions. To study the impact of this on the quality of welds produced, X-ray reports were scanned once again and the results tabulated. For TIG welding, distinction between defects produced in overhead and down-hand position could not be made because of the present method of radiographing welded joints. The results show that for TIG welding, about 80% of the defects occur in the overhead and down-hand positions and only 20% in the vertical position.

Welder-wise Analysis

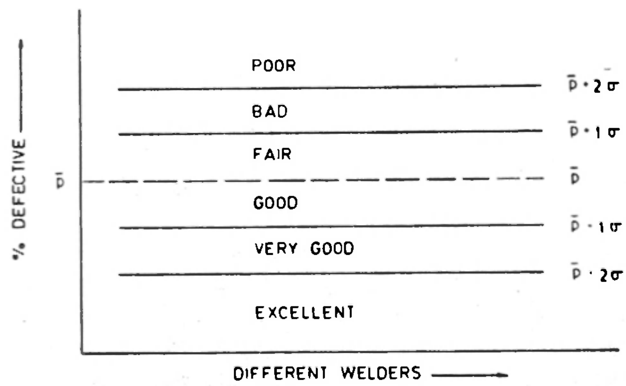
The present system of rating a welder engaged in welding these joints is based on the percentage of defective joints produced by him regardless of the total number of joints welded by him. Also, TIG and gas welders are rated together based on the same standard of evaluation.

It was noted that the welders engaged in the welding of these joints were qualified to the same procedures and standards as required under the code of construction and inspite of this, there appeared to be a significant difference in their performance. More scientific evaluation of welders was done on the basis of p-chart (Fig. 5). It was also observed that the good welders so identified in TIG welding were avoiding overhead position which was more prone to production of defective joints.

Analysis of Acceptance Sampling Plan

Fig. 6 is a p-chart for stub joints of 210 MW spirals.

The existing sampling plan was analysed for 'Average Outgoing Quality Limit' i.e. quality of lots in the long run and for 'Probability of Acceptance' at existing quality level. In the existing plan, for a lot of 30 spirals welded by one particular welder, a sample size $n_1 = 3$ is taken for inspection. If no weld joint fails, then the lot is passed but if one joint fails another sample of $n_2 = 3$ is taken. If none fails, then the lot is passed but if one or more joint fails then 100% inspection of the lot is to be done. Its interpretation shows that :



SYSTEM OF EVALUATING WELDER'S PERFORMANCE

Fig. 5

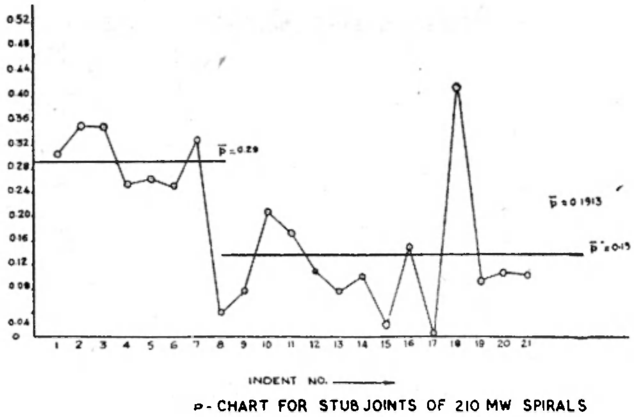


Fig. 6

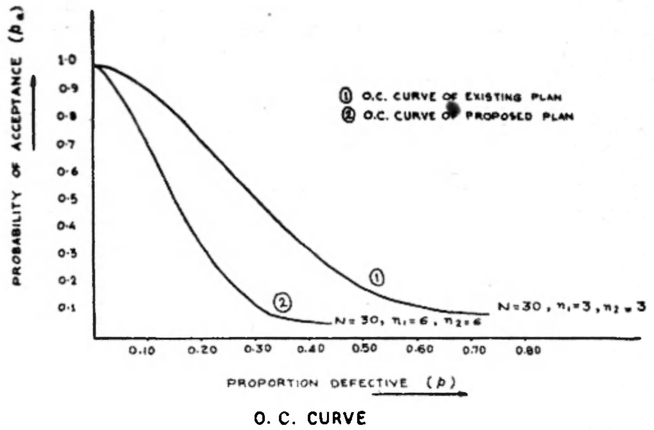


Fig. 7

1. at the present quality level of 13.2%, the probability of acceptance is 88%. (Fig. 7)
2. past data revealed that proportion defective could go as high as 30%. Such lots should be detected in majority of cases. Under existing sampling plan, such a lot has 50% probability of getting through.
3. Average Outgoing Quality Limit is 15.5%. (Fig. 8)

This calls for a better sampling plan which can detect bad lots with a higher probability. Under the proposed plan, a first sample size $n_1 = 6$ is to be inspected from a lot of 30 spirals welded by one welder. If none fails, the lot is passed but if one fails, another sample size $n_2 = 6$ is to be taken for inspection. If none fails, the lot is passed but if one or more fails then inspection is to be carried out on the rest. The proposed sampling plan with the following features eliminates the lacunae of the existing sampling plan :

1. the probability of acceptance at existing quality level of 13.2% is 65%. (Fig. 7)
2. the probability of accepting lots with 30% defectives is only 10%.
3. Average Outgoing Quality Limit is 7.5%. (Fig. 8)

Analysis of Inner diameters of Stubs and Spirals

Root offset between stub and spiral is not desirable as it is responsible for defects like lack of fusion, lack of penetration and root concavity though BS 2633 gives for joints with root gap a maximum permissible root offset of 0.8 mm for diameters less than 100 mm.

Analysis of the variations in inner diameter of stubs and spirals was done. It revealed the following :

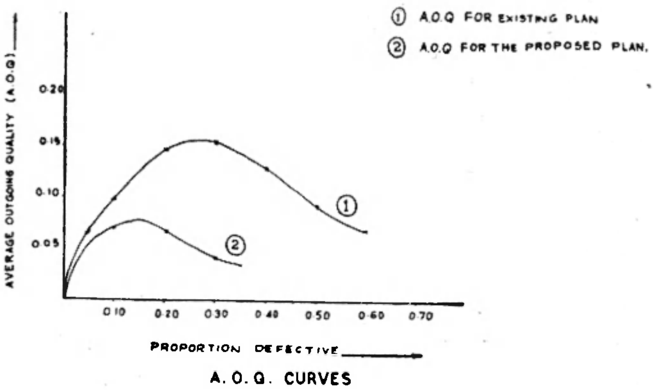


Fig. 8

1. I.D. of stub varies from 21.5 mm to 22.68 mm exceeding the specified limits of $22.0^{+0.2}_{-0.0}$ mm. This indicates a large process variation at the sub-contractor's end.
2. The I.D. of spiral tubes falls within the specified limits.
3. Average root offset between stubs and spiral tubes is 0.25 mm and maximum root offset is 0.75 mm.

Recommendations and Follow-up

1. Mixing-up of lots prevents identification of quality levels of individual lots on a day-to-day basis. To avoid this, formats have been prepared in consultation with QA Engineer, which are to be filled up by respective functional groups.
2. Random inspection of tack-welded joints must be carried out because improperly assembled joints may lead to rejection and rework.
3. To eliminate the 'difficult' welding positions, as identified during the course of study, a simple welding fixture has been suggested.

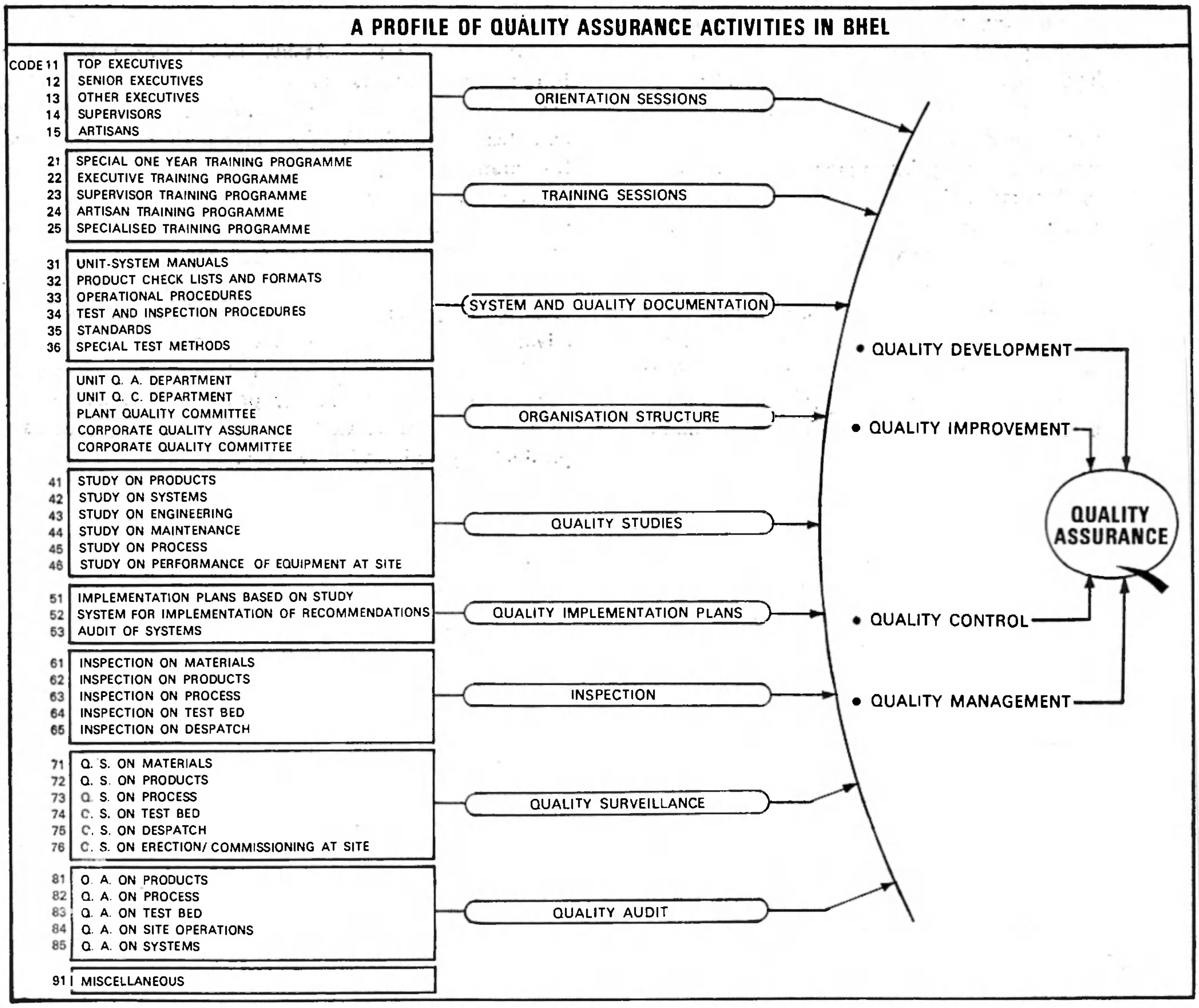


Fig. 9

4. The vertical position of welding gives minimum defective joints as compared to the overhead and downhand positions. Thus the X-ray must be taken in such a manner that the overhead and downhand positions appear along the major axis of the ellipse in the radiographic film. This will give a better clue to causes of welding defects produced.

5. TIG and gas welders must be rated separately on the basis of p-chart.

6. The p-charts and welder performance tables must be explained to the welders and maintained at the respective welding booths. This feed-back system is bound to have an effect on the quality of weld joints.

7. For the present quality level, the proposed sampling plan must be used as it provides a better protection against passing of bad lots.

8. The present system of documentation does not give any scope to identify the various welding parameters that go into the process. Once such data are maintained for different batches, a statistically designed experiment can be run to identify the critical factors contributing to the quality of welded joints.

2.3.3. Similar quality studies undertaken in different situations have indicated the possibilities of application of scientific methods of Statistical Quality Control for developing Quality Assurance systems for welding operations at the shop floor. Such studies undertaken by various industries will result in improved welding control practices that will inevitably lead to better plant performance, thus benefitting both the supplier of the industrial plant as well as the user. Application of specialised techniques using Orthogonal Array concepts in Industrial Experimentation designs also opens up possibilities of scientific and technically valid optimization of different parameters in welding operations for ensuring product quality, achieving better productivity and leading to cost reduction. Personnel involved in welding should get exposed to these methods of study and management so that the benefits of their work will ensure better quality of welding.

3. Conclusion

A total system of Quality Management has been found necessary to establish Quality Assurance in welding in Industry. Fig. 9 shows a profile of Q.A activities in BHEL. Studies have highlighted the need for sound Quality Engineering practices. Intensive quality case studies on shop floor operations bring out the factors affecting quality and application of Statistical Qua lity Control techniques and methods point out rational methods to formulate a Quality Assurance system for shop floor operations. Employing advanced techniques using Orthogonal Array concepts in Industrial Experimentation design will enable us develop welding technology process parameters and control procedures that will optimize cost, increase productivity and lead to assured Quality.