Technical Specification for Development, Supply, Installation and Performance demonstration of the Vision-based Inspection System for Appendage Welded tubes

1. Preamble:

Lustrous metallic tube of about 500 mm long chamfered to 'V' shape with included angle 120^0 is welded with several tiny metallic components (Type I, Type II & Type III or appendages) at pre-defined axial or circumferential locations. The size and orientation of these components are also pre-defined (Type-I: 30 x3 x 1-1.4 mm; Type II: 9X3X0.7-1.0mm; Type III: 9 X3 X3.3 mm, Approx. LengthXWidthXHeight). The top surface of components is smooth and bottom surface welded to the tube are having projection. Finally the assembly is subjected to visual examination for detection of defects like absence of these components, wrong orientation, reverse orientation of top & bottom surface, shifting of these from desired location either axially or circumferentially as well as subjected dimensional measurement like total length of the tube, distance of the components from tube end, tube end chamfer thickness etc.

The system shall be used to replace the manual measurement which is presently done by different gauges on sample basis for each welding machine. The automated system shall be capable of inspection of following features for all the assembly variants with high degree of accuracy, precision and repeatability with data recording facility.

(a) Measurement of total length of the tube

(b) Distance of the welded component (Type I, Type II & Type III) from tube end

(c) Inspection of component (Type II & Type III) angle and orientations

(d) Inspection of component (Type I) axial alignment

(e) Visual examination for detection of defects like absence of these components, wrong orientation of these components, reverse orientation of top & bottom surface, shifting of these from desired location either axially or circumferentially etc.

(f) Inspection of tube end chamfer

Typical dimensional features are indicated with sketches shown in Fig.1-4.

There are two different sizes of tube being used for these assemblies' viz. 13 mm and 15 mm dia. weighing about 60 gm each. There are five variants w.r.t number & types components welded for 13 mm dia. and three variants w.r.t number & types components welded for 15 mm dia.

2. Description of Test Object:

a) The material is Stainless Steel or equivalent

b) Color: Metallic color similar to Stainless steel with specular surface

c) The edges of the tube ends are chamfered to 'V' shape with included angle 120^0.

d) Tube straightness is within 1/1200 mm

e) Several tiny metallic components (appendages) are welded at pre-defined axial or circumferential locations. The size and orientation of these components are also pre-defined.

f) The top surface of components is smooth and bottom surface welded to the tube are having projection.

g) <u>Dimensions:</u>

I. For Cat-I Assemblies (3 variants):

a. Tube length : 490 mm±0.05 mm
b. OD : About 15 mm
c. Thickness : About 0.4 mm
d. End squareness : 0.05 mm on both the side
e. Distance of components from tube end:
   (1) 50 mm±0.5 mm (from tube ends to Type-I components present at the ends)
   (2) 230±0.5 mm (from tube end to Type-I components present at the centre)
   (3) 240±0.5 mm (from tube end to Type-II component present at the centre)
f. Central distance of tube : 245 mm±0.05 mm
g. Component thickness above tube : 1.3 mm max.
h. Angle between component axis and tube axis: 15˚±2˚

Table-2: Component orientations across the circumferential direction (angular position):

Variant	Type	No. of components	Orientation of Type-II Component
V1	Central	6 (Type-I)	Equally-spaced (60˚)
V2	Inner	5 (Type-II)	60˚,90˚,60˚, 60˚, 90˚(Anticlockwise)
V3	Outer	3 (Type-I) & 3 (type-II)	60˚, 90˚, 105˚, 105˚ (Anticlockwise)

II. For Cat-II Assemblies (5 variants):

a. Tube length : 490 mm±0.05 mm
b. OD : About 13 mm
c. Thickness : About 0.4 mm
d. End squareness : 0.05 mm on both the side
e. Distance of components from tube end
   (1) 50 mm±0.5 mm (from tube ends to Type-I components present at the ends)
   (2) 230±0.5 mm (from tube end to Type-I components present at the centre)
   (3) 240±0.5 mm (from tube end to Type-II&III component present at the centre)
f. Central distance of tube : 245 mm±0.05 mm
g. Component thickness above tube : 3.3 mm max.
h. Angle between component axis and tube axis: 15˚±2˚

Table-1: Component orientations across the circumferential direction (angular position):

Variant	Type	No. of components	Orientation of Type-II&III Component
V4	Central	6 (Type-II)	Equally -spaced (60˚)
V5	Inner 1	5 (Type-II)	60˚,90˚,60˚, 60˚ 90˚(Anticlockwise)
V6	Inner 2	5 (Type-II)	65˚,55˚,90˚, 90˚, 60˚ (Anticlockwise)
V7	Outer 1	3 (Type-I) & 3 (Type-II)	70 ˚,90˚, 100˚, 100˚ (Anticlockwise)
V8	Outer 2	3 (Type-I), 2 (Type-II), 2 (Type-III)	54˚,52˚,54˚,100˚,100˚(Anticlockwise)

Typical orientation of welded components on tube as shown in Table 1

3. Scope:

The scope shall include the design, development, supply, and installation and performance demonstration of the vision-based inspection system for appendage welded tubes. The system shall be capable of surface examination and measurement of features as mentioned above [clause-1(a-f)] for all the assembly variants.

The system shall be independent and will not be intergraded to any other process equipment. The system shall be capable of automatic pick-up, inspection, sorting of accepted or rejected assemblies and data logging of inspection result.

The major sub-systems shall be following:

a) Tube feeding or handling system for giving input to the inspection station

b) Inspection station(s) for surface examination and dimensional measurement

c) Automatic sorting system for segregating the accepted and rejected assemblies in respective bins or tray.

d) PLC based Control System and Data acquisition system.

4. Description of the sub-systems:

a) Tube feeding or handling system for giving input to the inspection station:

A basket of suitable dimension shall accommodate the assemblies. Tubes pick up and place mechanism based on servo drive shall place the tube at vision-based inspection and measurement station (s). Capacity of table or tray shall be designed such that min. 300 nos. of tubes shall be loaded at a time. Hopper or table shall be fabricated with material which will not cause any scratch or physical damage on the test object.

b) Inspection station (s) for surface examination and dimensional measurement

This is the heart of this equipment. Main features of this sub system shall be following:

- This system shall be vision based which is fully automatic, non contact type and shall not require any manual intervention.
- Camera having adequate resolution with tele-centric lens, proper illumination systems and image-processing software shall be used.
- The tube could be rotated for covering entire circumference for detection and measurement on features on tube surface.
- End chamfer features shall also be inspected
- Mechanically isolated so that external factors do not influence the measurement.
- Whole measuring mechanism shall be simple, very fast to have high degree of accuracy and repeatability.
- System shall be capable of replacing sample basis check by 100 percent check.

c) Tube sorting system in accepted and rejected bins or trays

After completion of inspection and measurement, assemblies shall be sorted as rejected & accepted. Two trays or bins shall be provided for collection on these tubes based on the inspection results. Trays or bins shall be fabricated with material which will not cause any scratch or physical damage on the test object.

d) Control panel, data acquisition & display system:

The control system with PLC controller and other pneumatic/ electric arrangement for material handling, measurement system and sorting of test objects for fully automatic operation & manual operation shall be provided.

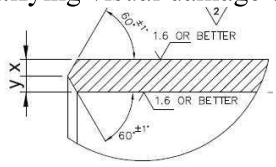
a. PLC Control system shall be provided for the entire operations.
b. The program shall be designed to have minimum cycle time.
c. PLC shall have 20 % spare inputs and 20% spare outputs for further augmentation.
d. PLC program project copy shall be supplied in CD-ROM/USB in English.
e. Interposing relays shall be used and shall be of reputed make.
f. The user interface will be through a large screen (HMI/PC). All alarms, messages and system status will be displayed on the large screen (min. 19" size).
g. Only screened cables shall be used and all the PLC connection shall be properly ferruled.
h. All the tubes measurement shall be saved in a folder with its batch or lot no. The batch no. shall be entered by operator before starting of inspection.
i. Dedicated data acquisition and storage software shall be provided for capturing image, processing & decision making, and recording test results.
j. Test results of accepted, rejected components with reason for rejection shall be displayed on the screen.
k. After completion of inspection, the report shall be generated with following detail. Batch/lot size, accepted qty., rejected qty. for different features, date, time and operator name.
l. Color Printer shall be provided for report printing.
m. Emergency switches shall be incorporated for easy access and to stop the complete machine immediately.
n. All the components/hardware used shall be reputed make.
o. System shall be provided with Computer table and ergonomically designed chair.

5. Test System Capacity and Functional requirement:

Sr.	Features	Functions
I	Scope of testing	(a) Measurement of total length of the tube (b) Distance of the welded components from tube end (c) Inspection of component angle and orientations (d) Inspection of component axial alignment (e) Visual examination for detection of defects like absence of these components, wrong orientation of these components, reverse orientation of top & bottom surface, welding of two components over one another, shifting of these from desired location either axially or circumferentially etc. (f) Dimension of tube end chamfer & detecting visual damage (g) Identifying inter-change of Type-I components with thickness difference of around 0.3 mm. (h) Identifying inter-change of Type-II components with thickness difference of around 0.3 mm.
ii	Test system type	Vision based inspection with image processing software, Automatic tube handling and sorting of the accepted or rejected assemblies
iii	Measurement accuracy	Linear dimension: ±25 micron or better, Angular accuracy:15' or better, however cumulative of all the component in a cross-section shall be within $\pm 0.5^{O}$
iv	Inspection speed	300 assemblies per hour
V	Measurement range	Shall cover the full length and circumference for orientation measurement
vi	Interface	RS 422, Ethernet
vii	Calibration	Fast Calibration with sample provided by purchasers
viii	General features	(a) The measurement accuracy shall not be affected by minor shallow scratches, Waviness on tube surfaces (b) The mechanical system shall not cause any scratches, Impression and handling marks on the tubes

6. Acceptance-rejection Criteria:

The features as mentioned below are typically shown in Fig.1-4.

Features indicated in Fig.1-4	Features	Specified
a	Measurement of total length of the tube	490 mm±0.05 mm
e3	Distance of the central Type-II & III component from tube end	240 mm±0.5 mm
e1 & e2	Distance of the Type-I components from tube end	50 mm±0.5 mm (for both ends), 230±0.5 mm (for central component)
g	Angle between component axis and tube axis	15˚±2˚
h	Inspection of component orientation across circumference (angular position)	As per Table-1&2. Angular accuracy for any single measurement shall be 15' or better. However cumulative of all the component in a cross-section shall be within $\pm 0.5^{O}$
i	Inspection of component axial alignment	All 3-components (Type I) shall be in a straight line
j	Inspection of tube end chamfer	End chamfer thickness both edges of 'V' shall be measured (x, y of the given sketch below). Minimum and maximum values in the cross section shall be measured. Difference between x and x shall be reported and shall not exceed 0.1 mm. End chamfer inspection for identifying visual damage of around 50 µm 
-	Visual examination for detection of surface defects	• Absence of any appendages/components • Reverse orientation of components top & bottom surface • Shifting of these from desired location either axially or circumferentially • Detection of components welded vertically • Identifying inter-change of Type-I components with thickness difference of around 0.3 mm. • Identifying inter-change of Type-II components with thickness difference of around 0.3 mm.
-	Measurement accuracy	Linear dimension: ±25 micron or better, Angular accuracy:15' or better
-	Inspection speed	300 assemblies per hour

7. Performance criteria:

a) At supplier's work:

The inspection and measurements of appendage welded tube shall match with the manual visual inspection and dimensional measurement with standard measuring instruments or gauges. False rejection shall be less than 5% of the number of samples inspected under the system; however no false acceptance will be permissible. The system performance will be checked at the supplier's work with atleast 300 assemblies at the inspection speed of 300 assemblies per hour during pre-dispatch inspection complying this specification and acceptance-rejection criteria as per clause-6.

b) At Purchaser's work:

Performance demonstration of the different inspection, measurement, sorting with all controls for at least two weeks of smooth operation inspecting at least 10,000 assemblies shall be ensured at the inspection speed of 300 assemblies per hour complying all the requirement of this specification before final acceptance at purchaser's site.

8. Supply of Manuals and Circuit Diagrams:

The supplier shall provide all the operating and maintenance manuals of entire system and sub-systems. These will contain description of the system, operating procedures, maintenance procedures along with catalogues of major brought out items, general arrangement and detailed as built mechanical drawings of all components & subsystem, electrical circuits, pneumatic circuit diagrams. PLC diagram and PLC application program copy with programming in English shall be provided along with system. Bought out items list with detail shall be enclosed in the manual.

9. Utilities Available at Purchaser's site:

a) Power Voltage: 415 V ± 6%
   Rated frequency : 50 Hz
   System supply : 3-phase
b) Compressed Air: Supply pressure : 5 to 8 Kg/cm2

10. Qualifying Criteria for Participating in the tender (Vendor evaluation):

(a) The vendor shall be in the fields of Automation involving pick & place mechanism and automatic handing of materials by servo drive and pneumatics, as well as Vision Based Inspection Systems since last 10 years. The supplier shall have manufactured and successfully executed at least one number of automated vision based measurement system for metallic components in the last 5 years. Documental evidence for the same shall be provided. NFC reserves the right to evaluate the capability of the firm.
(b) The supplier shall have necessary facilities to provide services in India.

11. General Requirements:

The system and all works shall conform in all respects to high standards of engineering design and workmanship. The inspection station (s) shall be enclosed with in glass/ acrylic box for protection against atmospheric dust and other undesirable conditions. The offer shall consist of- a) General arrangement drawing and scheme of his proposal.

b) All the items used shall be of reputed make.

Further following to be noted:

a) The successful vendor has to submit hardcopy of drawings and the technical proposal along with soft copy of the drawings in 2-D/3-D within 30 days from the date of PO placement, for approval, before the commencement of the work.

b) The system shall be complete with all auxiliaries, safety features, electrical, instrumentation etc., as required for smooth and trouble free operation of the system. The system supplied shall meet the performance requirements as specified in the document.

c) The system and all works shall conform in all respects to high standards of engineering, design and workmanship and be capable of performing in continuous commercial operation in a manner acceptable to purchaser.

d) The Packing, forwarding & safe transportation and delivery of items up to purchaser's site shall be done by the supplier/Vendor.

e) Any tools, tackles instruments and other consumables required for erection and commissioning has to be provided by supplier at his cost.

f) During the erection and commissioning period, supplier shall be responsible for accommodation, transportation, welfare of his staff and his representatives involved during erection and commissioning. Purchaser shall not be liable to pay any compensation for losses arising out of injuries.

12. Warranty:

The supplier shall provide warranty for at least 12 months after successful installation, commissioning and final acceptance of the system at purchaser's site.

13. Installation, commissioning & Training

Supplier shall carry out installation & commissioning of the system at Purchaser's Site (NFC-K site, Rawatbhata, Rajasthan,) and provides training to at least 3 NFC personnel at Purchaser's site over a period of atleast 1 week.

14. Optional Requirement:

(a) Spares & accessories:

The supplier shall quote for necessary spares and accessories felt necessary for five years of trouble-free operation of complete system. The supplier shall quote for these spares separately.

(b) Measurement of component Height above tube surface which are welded axially.

15. Mandatory spares:

Following mandatory spares are required to be supplied along with each system.

Sl. No.	Item description	Quantity
1.	Telecentric lens	1 No used each type
2.	Light	1 No used each type
3.	Camera	1 No used each type
4.	Sensors and switches	1 No used each type
5.	Servo components	1 No used each type
6.	Pneumatic components	1 No used each type

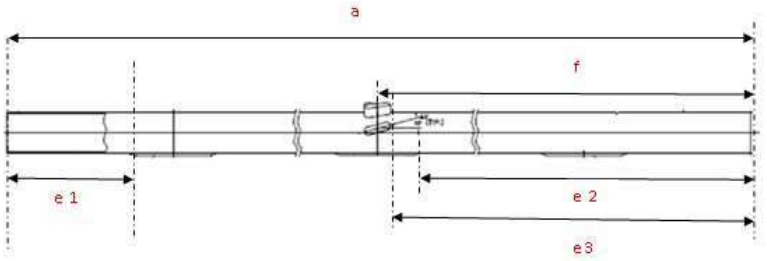


Fig.1a:Typical front view of tube welded with components

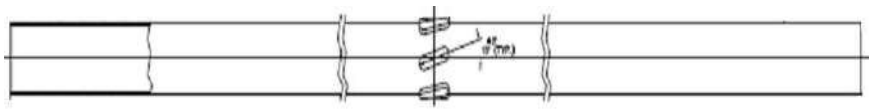
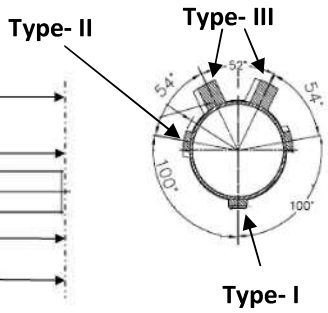
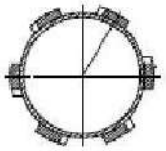


Fig.1b:Typical front view of tube welded with components at centre



End view with Type I, ,II & III (h)



End view with Type-II components having 60^0 spacing (h)

Fig.1(a-b): Typical orientation of welded components on tube

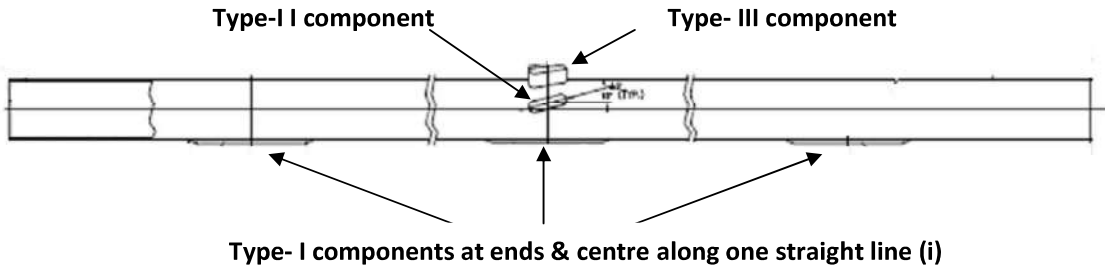


Fig.2: Different components welded on tube surface

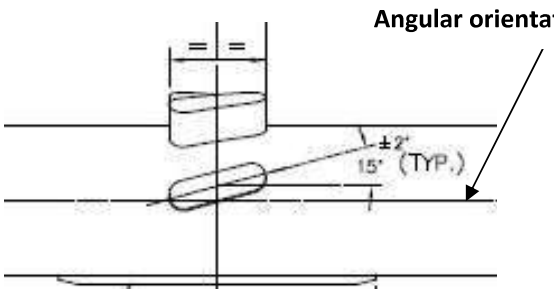


Fig.3: Angular orientation of Type-II & III components at centre (g)

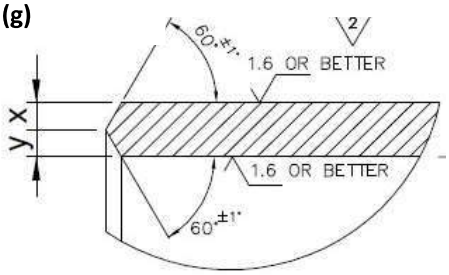


Fig.4: Tube end chamfer features (j)