# Testing and Calibration of Temperature Gauges using Webcam based Non-Invasive Technique

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## ABSTRACT
In this paper, a contact less testing and calibration system is developed for temperature gauges. The system captures the images of temperature gauge at a regular interval, detects the desired region of interest using algorithms and segments the needle for further processing. The segmented image properties are calculated and matched with the standard data to indentify the indicated value. The system is capable enough to generate alarm and emboss 'defective sample' on the gauge under test. In the field manufacturing, non invasive visual inspection systems are replacing the need of human inspector to prevent the inclusion of incorrect parts or to check the quality of goods.

## General Terms
Calibration and Testing

## Keywords
AVIS, Image Acquisition, NITCS, ROI, Threshold.

## 1. INTRODUCTION
In mass-production process, 100% quality achievements are always a line of demand for all finished products. To achieve this goal, automatic visual inspection systems(AVIS) [1]-[8] are found very much suitable because of its reliability, robustness, consistent performance, low running cost, flexibility in applications, user friendly, fast, high accuracy, mass production capability and hence reduction in the cost of the products, and low failure rate. It also helps in identifying functional and cosmetic defects. The use of visual inspection for finished product becomes a necessity to fulfill the industrial quality standards. It is now the adaptive ethical policy that products should not be shipped to customers if it is not gone through quality check and gives guaranty for defect-free. In fact, the human visual inspectors are best between 70-80% inspection levels but visual inspection system (VIS) enhances this level to 99.99 % [5]-[11].

The prevalence of visual inspection applications is to hunt the decipher quality problems by using artificial intelligence techniques, model-based visual inspection techniques, and imperfection detection techniques. The main objective of these applications is to eradicate imperfect goods from the manufacturing process before additional value is added to the faulty product or before the faulty product is released to the consumer. Therefore, inspection systems are meant to monitor all manufacturing steps and report the defects rapidly.

The automatic visual inspection systems (AVIS) are non-invasive in nature hence risk of product damage during inspection is negligible. An Automated visual inspection is viable for the use of large part volumes, accurate measurements, and 100% inspection in hazardous location. It helps in yielding the greater customer satisfaction, lowering production costs and increasing market shares [12]-[15].

## 2. PROPOSED VIS MODEL
Initially, the visual inspection systems were applied in the manufacturing industries because there was a sturdy need to automate the manufacturing process and to monitor the final goods. In this process, the goods are checked for permitted tolerance bands of given standard, functional or superficial defects. Afterward the VIS are modified and made capable enough to sort the defective products from the process. In the beginning, human inspectors were employed in process and manufacturing industries to carry out the tasks of visual inspection. Now, the complete inspection scenario is changed and human inspectors are replaced by smart visual inspection systems with more accurate results and robust performance.

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### 2.1 Existing System
Figure 1 represents the existing manual testing and calibration system which has to be replaced by the visual inspection system. Figure 2 (a) shows the gauge to be tested and Figure2 (b) represents the electrical equivalent diagram of gauge. The calibration is done by changing the resistance of variable resistance ($R_2$) as per the values mentioned in Table 1 for the particular temperature position. If the needle is found exactly overlapped with white line marked on the gauge for particular temperature when $R_2$ is set accordingly then that position is marked as 'OK' otherwise 'NOT OK'.

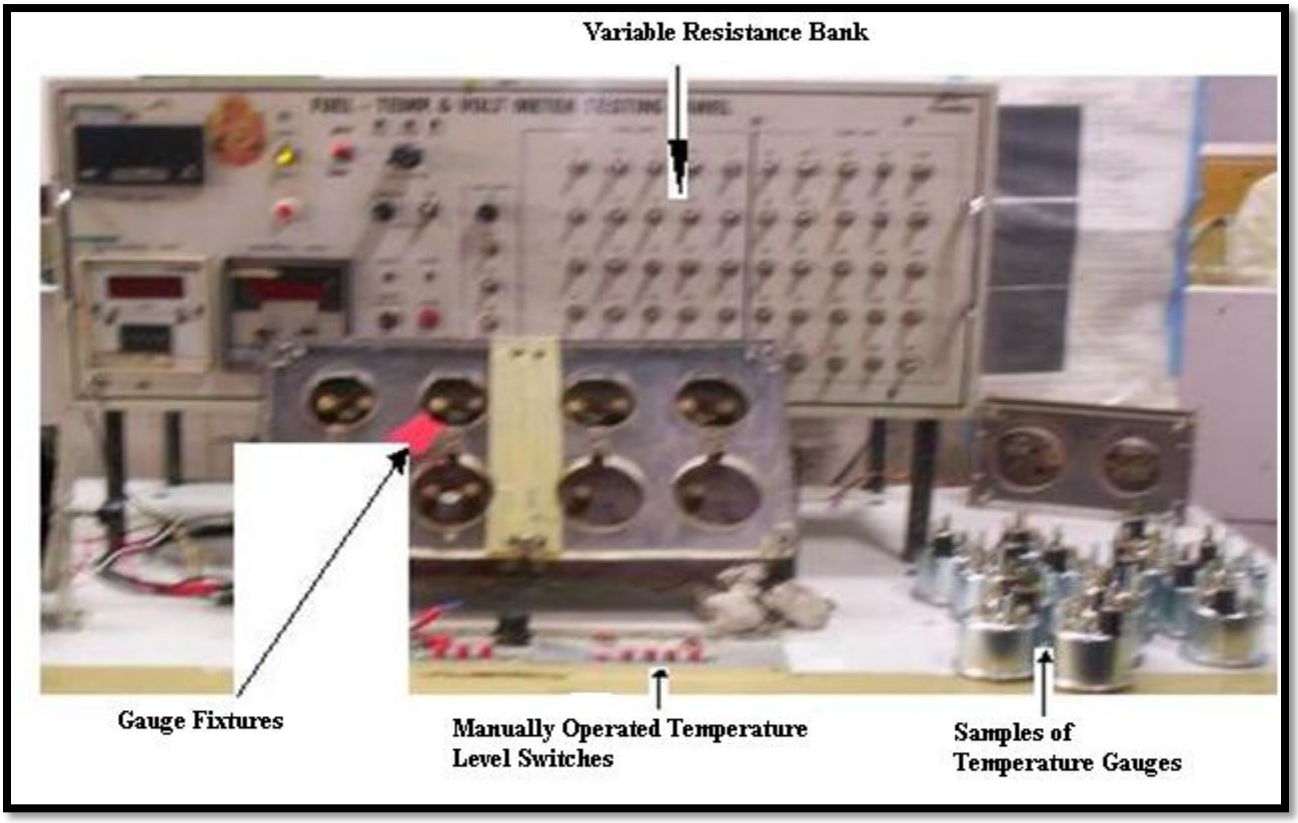
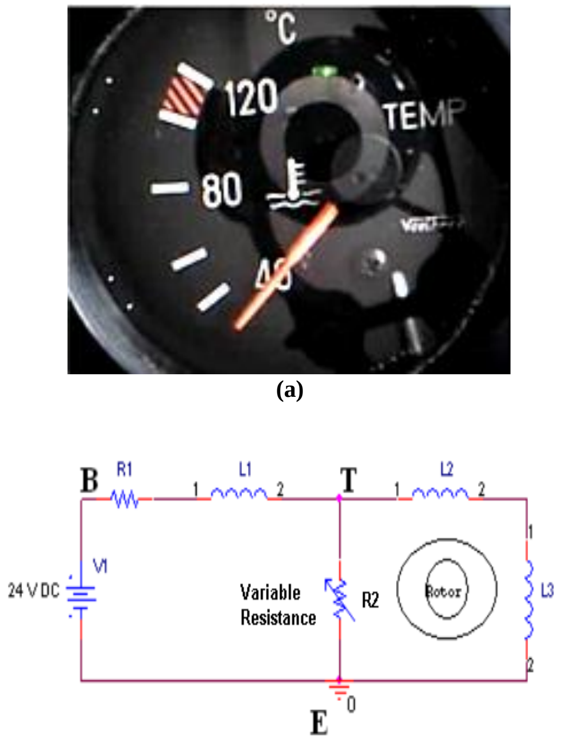



**Fig1: Existing manual testing system**

## 2.2 Gauge Model and System




**(a)**

**(b)**

**Fig 2: (a) Gauge to be tested (b) Electrical equivalent circuit of gauge**

**Table 1.Temperature Vs electrical parameters of gauge**

| Serial No. | Standard Temperature Levels in °C | Resistance Value (in Ω ohms) | Tolerance Ω |
|---|---|---|---|
| 1 | 40 | 500 | 1 |
| 2 | 60 | 238 | 1 |
| 3 | 80 | 120 | 1 |
| 4 | 100 | 66 | 1 |
| 5 | 110 | 50 | 1 |
| 6 | 120 | 38 | 1 |

## 2.3 The art-map of Non-Invasive Testing and Calibration System (NITCS)

The art-map of non-invasive testing and calibration of temperature gauge is shown in Figure 3. It includes three modules viz: hardware, software and image acquisition. The hardware module consists of interfacing circuits, relays, and various displays and indicators. The software module consists of programs for image acquisition, processing, decision making, and display of results and image acquisition module consists of web camera, illumination, and gauge fixture alignment arrangements.

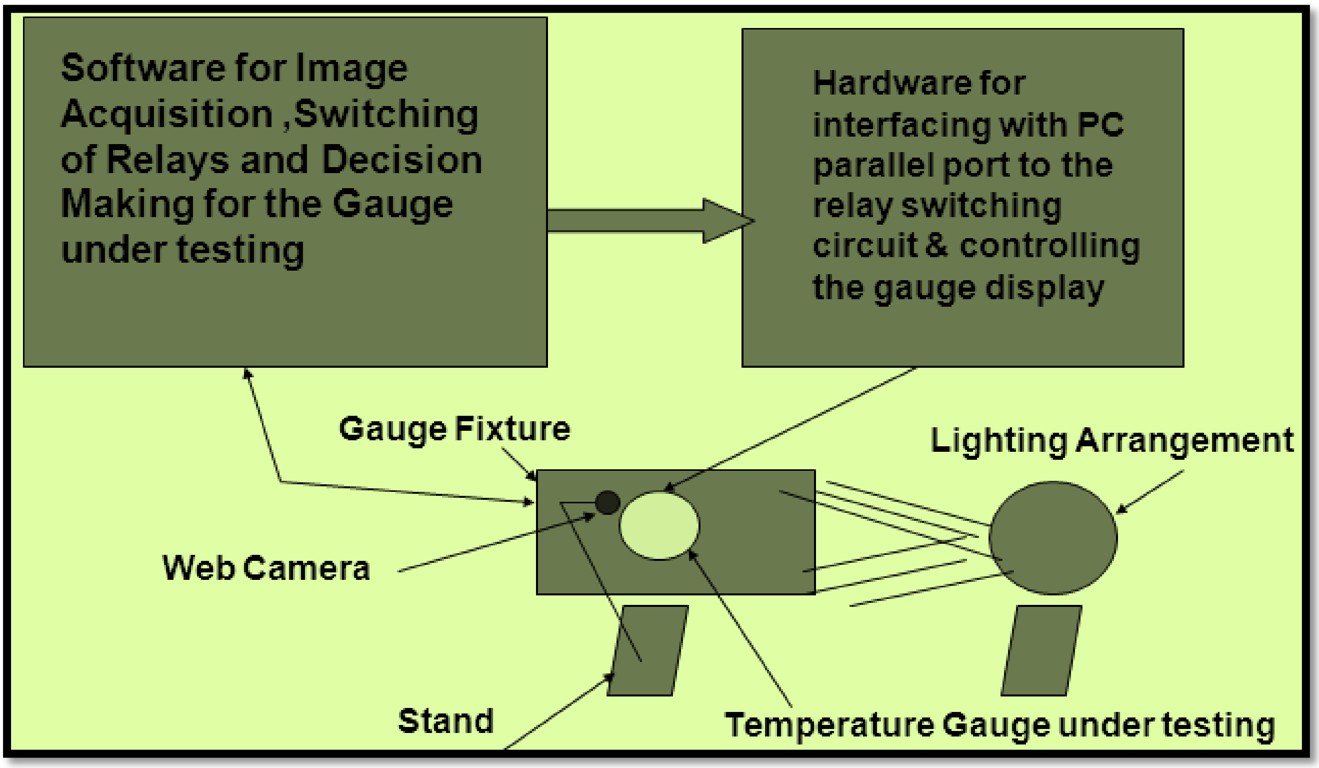



**Fig 3: Art-map of non-invasive testing and calibration of temperature gauge model**

## 2.4 Image Acquisition

The most important aspects of visual inspection system are image acquisition, because the quality of image sturdily influences the reliability of the system. The quality of captured image depends upon illumination, resolution of camera, reflectance [14] of object under test, angle of camera, and distance of camera from object. A smart optical sensing system reduces noise and blurring of image and hence fastens the inspection system. In this application web camera is used to capture the images in a sequence.

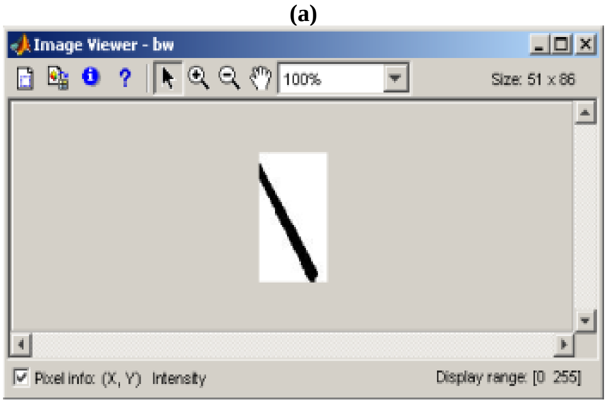
## 2.5 Segmentation

The threshold based segmentation technique is used to detect the pointer's image from the captured image [16]-[19]. The region of interest (ROI) selection algorithm is same as proposed by [18]. Figure 4(a) represents the RGB image in the selected ROI and Figure 4 (b) represents the segmented black & white image of the pointer.

## 2.6 Image Feature Calculation and Matching

The features of segmented black and white image are calculated using the algorithm proposed by [18]. In this, geometrical and statistical feature of segmented image is calculated and matched using principal component analysis (PCA). If all the image features of segmented black and white image are same as the image features of that location in the gauge then the indicated value is recognized and accept (OK) signal is generated otherwise reject(NOT OK) signal is generated[20]-[23].

(a)




(b)

**Fig 4: (a) Image in ROI (b) Segmented black & white image of pointer**

## 3. IMPLEMENTATION

The experimental setup of NITCS is shown in Figure 5. The flow chart of NITCS is given in Figure 6. The proposed algorithm is implemented using MATLAB program. The graphical user interface (GUI) is also developed using MAT LAB to make the NITCS user friendly as shown in Figure 7. Figure 7(a) represents the main window while Figure 7(b) represents the setting window to set various parameters. All simulation is done using Core 2 Duo processor T5670 @1.80GHz, 1GB RAM.


**Fig 5: Experimental Setup of NITCS**

## 4. RESULTS

The NITCS implemented successfully and results are shown in the Figure 8 and 9. The gauge under test is checked for all steps of temperature gauge dial. If image feature of is matched with the all corresponding values the 'OK' i.e. accept is displayed as shown in Figure 8 and if not matched then 'NOT OK' is displayed as shown in Figure 9. If one or all steps displayed 'NOT OK' the final result is concluded as "NOT OK' i.e. reject.

**Table 1.Comparison of NITCS with the existing manual system**

| S. No | Comparison Factors | Manual System | NITCS |
|---|---|---|---|
| 1. | Type of Operation | Invasive | Non Invasive |
| 2. | No of gauge inspected per hour | 40- 45 | 60-62 |
| 3. | Testing efficiency of the system | 72-78 % | 95-100% |
| 4. | Reliability | 65-70 % | 99.7 % |
| 5. | Quality assurance | 82-85% | 99.9 % |
| 6. | Human factor | 70% | 5% |
| 7. | Environment factor | 20-25% | 5-10% |
| 8. | Re payment of installation cost | 20-25 days | 5-10 days |
| 9. | Running cost | More | Negligible |
| 10. | Maintenance Required | Routinely Required | sporadically Required |
| 11. | Flexibility in adaptability of new technology | Whole system requires modification | Can be modified easily |
| 12. | Operation | Complicated | Simple |

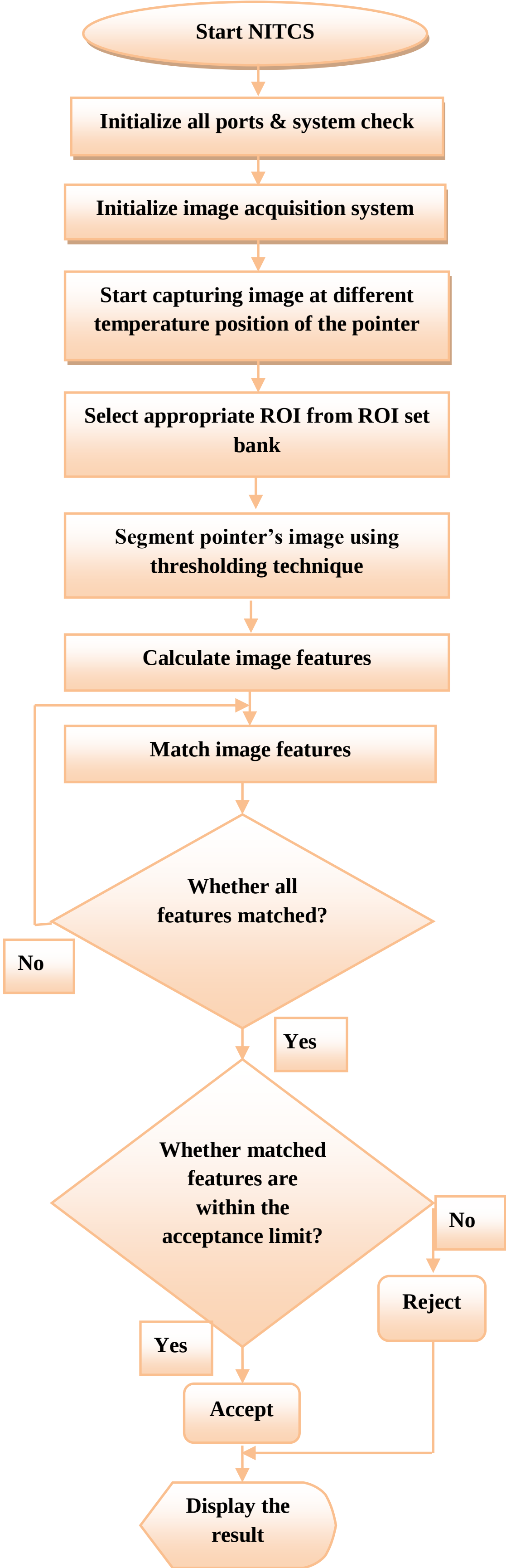
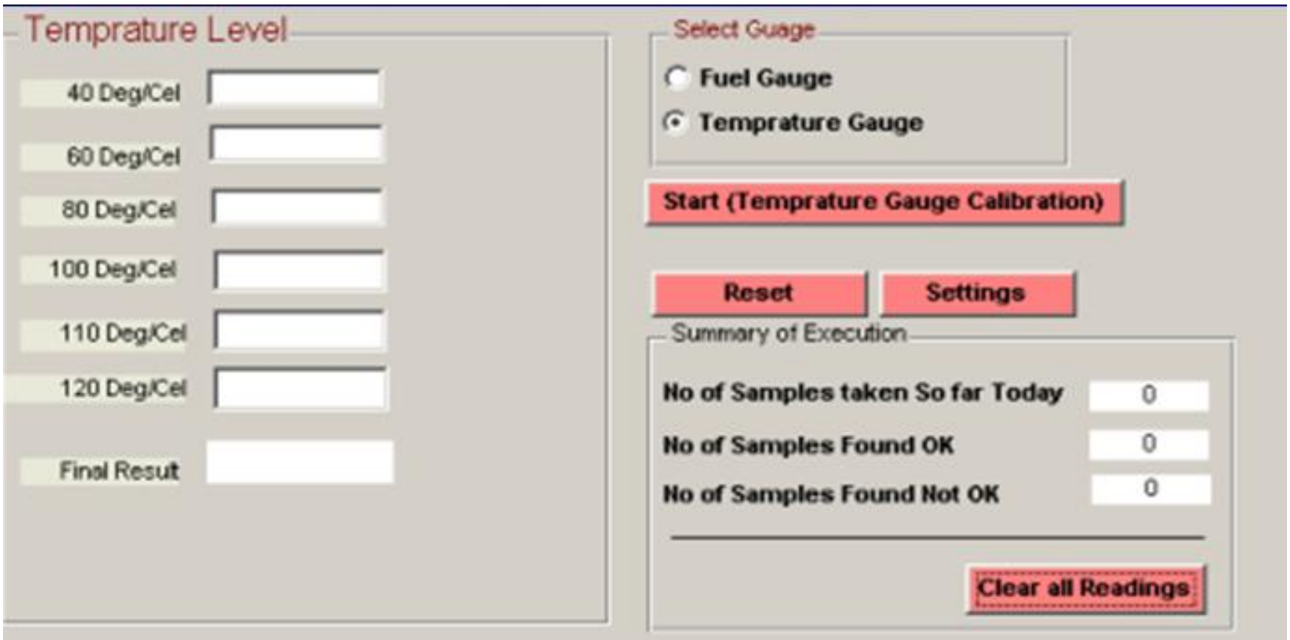
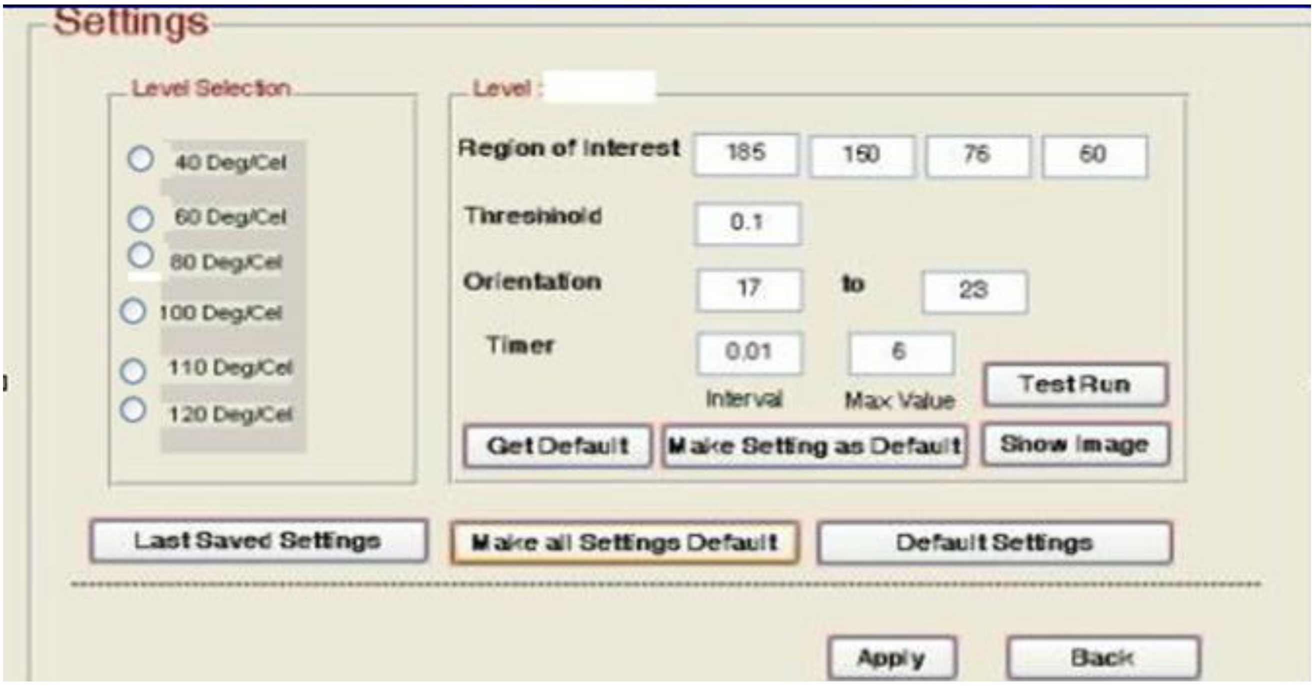



**Fig 6: Functional flow chart of NITCS**




**(a)**




**(b)**

**Fig 7: (a) Main window of NITCS (b) Settings window to set various parameters for processing**

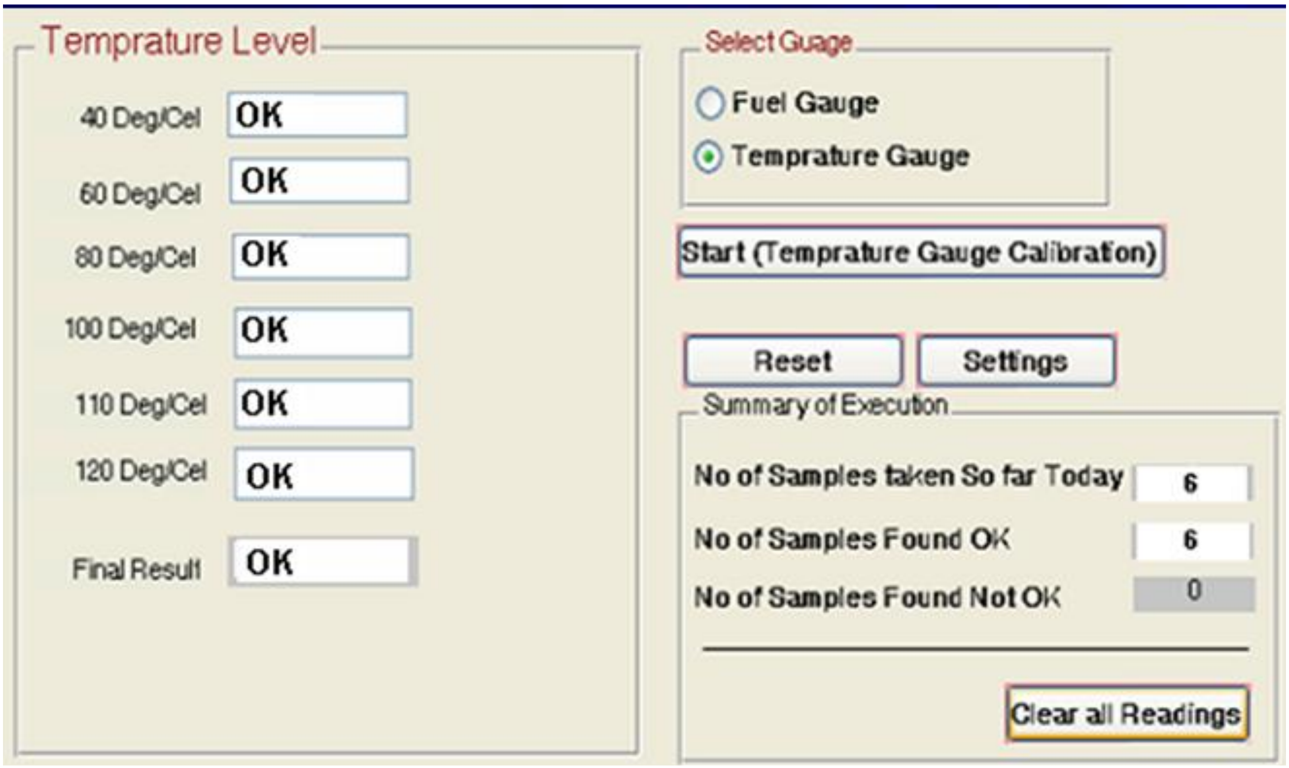



**Fig 8: Results when gauges found OK**

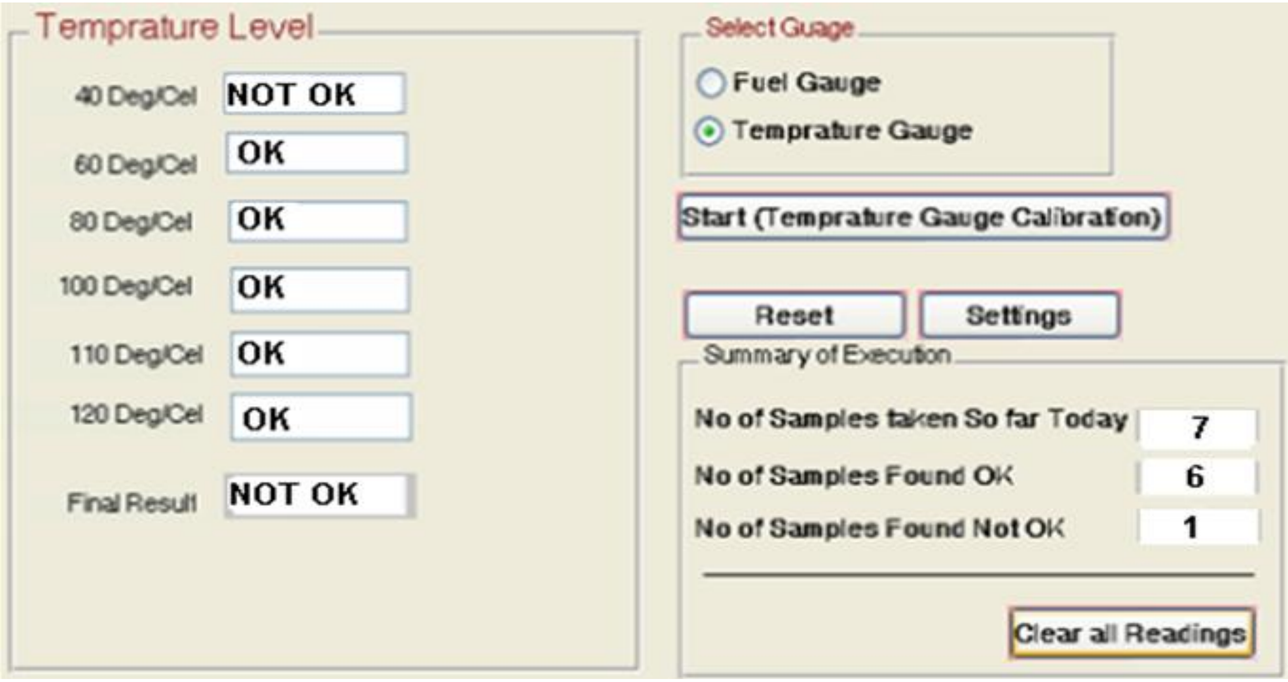



**Fig 9: Result when gauge is NOT OK**

## 5. CONCLUSION

The visual inspection system designed is completely user friendly, reliable, fast, and accurate. It reduces the cost of products up to a great extent. It enhances the quality assurance and hence improves the likeness of the product in the market. The proposed system had shown the consistent inspection performance. This concept of inspection system can be extended for the testing and calibration of other analog measuring instruments e.g. Wattmeter, ammeter, voltmeters, speedometers, and pressure gauge etc.

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