iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68561

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

A Study on the Occurrence of Discouloration / Blackening / Dezincification / Corrosion on 7.62 mm Ball Ammunition Manufactured by Ordnance Factory Varangaon

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Abstract: This study examines the persistent degradation of 7.62 mm ball ammunition from Ordnance Factory Varangaon (OFV), characterized by unwanted changes in appearance and structural integrity. Using a combined analytical and qualitative approach, the research assesses the success of modified protective treatments, the role of sulfur-based contaminants, and the effects of storage and packaging. Key results demonstrate that sulfur, originating from packaging and wax, is a significant cause of surface blackening. Furthermore, while the new protective coating process requires thorough confirmation, relying solely on immersion cleaning proves insufficient for preventing recurring corrosion. The research concludes by suggesting ways to refine the protective coating process, investigate new cleaning techniques, and establish a system of continuous assessment to enhance product quality and user satisfaction. This research provides insights into quality management within ammunition manufacturing, emphasizing the need for robust evaluation, process verification, and innovative approaches to solve longstanding corrosion and degradation problems.
Keywords: Discoloration, Blackening, Dezincification, Corrosion, Passivation Process, Sulfur Contamination, Ammunition Quality Assurance. JEL classification: 016, G21

I. INTRODUCTION

Various Depots had reported "Blackening of 7.62mm Belted Ammunition" in the year 2012. In situ inspection carried out by SQAE(A) VarangaonandOF Varangaonatvarious locations from 2013 onwards.CQA(A) vide letter dated 17 Oct 2013 approved the method of rectification as suggested by SQAE(A) Varangaon through its letter dated 25 Sep 2013 by the method of Hand Rumbling with toluene, and Cotton.CQA(A) vide letter dated 14 Nov 2014asked CQA(Met) whether to approve Hand Rumbling with Toluene Method or any other method.

CQA(Met) vide Letter No CQA(M)/QA- 2/7.62mm/Amn/vol- 04 Dt 04·Dec 2014 replied that "Use of Chromic Acid solution (Prepared usingSulphuric Acid & Distilled waterhas beenfound to be effective in removing SuperficialBlack StainsonBrass CartridgeCase. However, Toluene Solution serves the intended purposeof black stains removal from the Cartridge Case, use of the same may becontinued".

CQA(A)constituted BOO tocarryout investigation for Poor Quality of Ammunition issued to Depot. BOO Recommended-(a)Alternate Packing Material to be explored. (b)'Gasket' of Box H5A to be treated as Critical input material. Strict QC/QA checks at AT Test. Accordingly, Mill board, Wax and Gasket were made 'Critical' Items.

A meeting was held on 23/04/2015 at CQA(A) under the Chairmanship of MajGenGJS Grewal, controller. Decisions taken were :-(a)Rectificationmethod: Hand Rumbling with Toluene and cloth to becontinuedtill finalization of alternative method. (b)CQA (Met) to form Study Group for suggestingbetter alternative method for rectification.

Based onHQ DQA (A)'s instructions,CQA(A) constituted Study Group vide letter Dt 06 Jun 2015. The terms of reference were also given by CQA(A). (Shri Muruqesan Committee).

Meanwhile, in May 2015, OFV nominated CSIR-NML(NationalMetallurgicalLab, Jamshedpur) vide letter dated 12 May 2015. On 20/07/15 OFV approached CQA(A) for introduction of recommendations of NML report.

SQAE(A) forwarded the details of "Methodology of removal of black layer" developed by CSIR-NML. (Interim Report) Details are :- 07 Nos combination of chemicals tried however recommended following 02 combinations:-

(a) Chemicals A. Ammonium per Sulphate (20%) + Citric Acid (10%) 0.5 Benzotrizol + Carboxymethyl Cellulose (15 %) Gel - Application : Bv Rubbing.

(b) Chemicals B. Hydrogen Peroxide (25%) + Nitric Acid (2%) + Ethanol (0.5%) and Sulphuric Acid (2%) Solution- Application /method - Dip Cleaning process. Also Suggested to replace Mill Board packing material with latest material e.g. VCI Corrugated Sheet or Safefoil VCI Poly Laminate.

The Study Group final report was submitted to HQ DQA(A) on 03 Dec 2015. Major findings are listed below:- OFV had changedthe production process and had removed cleaning and washingoperation with Niogen after necking and tapering operation and final Baird Barrel Washing operation before tip annealing, and in its place had incorporated Degreasing, Brightening and PassivationwithChemicalsRustokik. Sealkote and Phosclean. The chemicals being procured for degreasing, brightening and passivation were proprietary items and details wrt specifications are not known.

During meeting held at OFV on 05-06 Nov 2015, it was brought out by repCSIR-NML that Brightening solution (Rustokik) may contain Sulphur and maybe the probable cause of blackening.

Sulphur content in Wax is not a parameter mentioned in the relevant Specn. However, during material testing, elemental Sulphur in Paraffin Wax samples were found to be 40 ppm at HEMRL, Pune and 2300 pm at CSIR- NML, Jamshedpur, which is a potential cause of Blackening in Amn. Water soluble Sulphate content in Millboard tested at CQA(ME), Pune was found to be0.39 % against Max 0.25% specified.

Blackened portion of Cartg cases tested at CQA(Met), lchapur were found to be containing high amount of Sulphur (14.07% for Worst affected, 8.50% for Moderately affected & 1.58% for Least affected Amn.

Blackened portion of Cartg Cases tested at CSIR-NML, Jamshedpur were also found to be containing high amount of Sulphur (14.35% & 18.64%). The report mentioned that wax may be the primary source of Sulphur contamination.

In view of the validation carried out by CQA(Met) and the NML report, the team opined that the Blackening of Cartg Case was primarily due to the presence of Sulphur.

During the meeting held at OFV on 05 & 06 Nov 2015, Rep OFV stated that Rusguard oil used in Belt Links and various solutions used for cleaningin the new process during mfr may also contain Sulphur.

During ISAT (A), Blackening was observed after first withdrawal, both in packed and unpacked Amn boxes (more prominent in packed amn boxes) with waxed Milboard, unwaxed Millboard and Cap Cell. Thus, it was concluded that wax may not be the only cause of blackening, and that there was a need for an alternate packing material and to review the production process and methodology of acceptance of input Material.

CQA(Metal), lchapur Test Report of Blackened Cartridge Cases showed that there was no de-zincification in the affected cases.

Rectification Proposal (CSIR-NML) as proposed by OFV was found satisfactory. Nochemical reaction/adverse effect/ abnormality were observed.

The proposed rectification method was only a corrective measure. OFV was to propose remedial/preventive measure for preventing recurrence of blackening during future production. This should include elimination of root cause as also improved packing material.

The recommendations of Study Group :-

Blackened /Affected Amn.

Dip cleaning Methodology suggested by CSIR-NML, Jamshedpur to replace existing Toluene based cleaning methodology. Efficacy of the rectification methodology to be ascertained by conducting ISAT(A) Trial.

OFV to take measures to prevent the Blackening of Amn during future manufacture.

OT Lots.

As Sulphur was identified to be the cause of blackening, all materials used in production process such as new cleaning solutions (in changed Process), input material (viz, Rusguard etc) or packing material, should be free from Sulphur and should therefore be tested for presence of Sulphur, even if testing of Sulphur is not part of specification.

Any input material which was now identified as thepotential cause for Blackening be treated as critical input material to be mutually decided by OFV and SQAE(A).

Any change in Process Schedule by the factory should only be carried out with knowledge of Resident SQAE(A).

Induction Heating Process to be introduced in place of Flame Heating process (which is being followed since 1970s) for Cartg Case Body Annealing Process.

II. ORIGIN OF THE PROBLEM

First case of Blackening/ Discoloration of cartg SA 7.62mm Ball / Tracer (Belted) Amn was reported in Dec 2012.

Blackening with 124 lots vintage 2008-2014 involving approx qty 2.5 crores were reported till 2017 and the lots were kept in segregated condition.

Complaints of Blackening/Discoloration of ammunition started coming since 2011-12. Thereafter, user i.e. Armed Forces started back loading the Ammunition since 2014-15 for rectification.

CQA(Met) after carrying out Metallurgical Examination/Tests on Cartridge samples through letterDt 05 March 2014 concluded that, "Tarnished appearance and black stains observed on the surface of the CartridgeCasesareconsidered to be an outcome of superficial surface reaction with some chemical reagent / environment and media / packing media during storage".

A Collegiate Meeting was held at MGO Branch under the Chairmanship of Maj Gen JS Menon, ADG EM for rectification of Amn (2.5 Crore). Decision taken:-

Blackened Amn.

Amn to be rectified byDip cleaning Method at OFV.

The rectified Amn would be subjected to Proof Firing and all procedures for release of a fresh Arnn be followed.

ISAT Trial will be carried out for 2 withdrawals.

Fresh Amn.

DGQA & OFB to manufacture a sample lot in Controlled manner by Stringent QC/QA at all stages.

The entire exercise of rectification & manufacture of fresh Amn would be monitored by the Task Force.

Based on MGO letter Dt 11 Dec 2015, CQA(A) vide letter No QA13200/blackening Dt 21/01/2016 intimated all concerned thatStudyGroup was re- constituted as Task Force.

Minutes of meeting dated 26/02/2016 :-

Rectification of back loaded Amn started in presence of Task Force (Dip cleaning method). Results of all test satisfactory.

Trial batch of Case and bullet manufactured using Option II & Ill (Fresh Amn).

As per the Minutes of Meetings Dt 21/07/2016, Task Force carried out ISAT Trials with waxed / unwaxed Mill board and PP corrugatedsheets. Results of Visual & Proof:-PPC Sheet – Satisfactory, Waxed - not satisfactory, Unwaxed – Satisfactory.

Till 2021 OFV received around 670 Lakhs of 7.62mm Ammunition out of which OFV rectified around 400 Lakhs by following the dip cleaning method approved by CQA (A), Pune. Passivation Chemical used during processing Cartg. Case was supplied by M/s Salts & Chemicals Kolkata. Firm never disclosed/revealed the Technical Specification of the Passivation Chemical.

The quality of the chemicals supplied by M/s Salt and Chemicals so deteriorated that during theproduction year 2021, 06 OT Lots (No 35/21,36/21,37/21,38/21,39/21 & 41/21) of A7 Ammunition got rejected by SQAE(A), Varangaon due to blackening issues. Assessing the gravity of the situation during the period, production of all the ammunition was stopped for 03 months. Various efforts were made by OFV for the improvement of the manufacturing process to address the issues of blackening. Help of CSIR-NML was also taken during the Process Improvement. After trial of various passivation chemicals, NML opined that the Chrome Passivation is the most stable.

III. DEVELOPMENT OF THE ISSUE

OFV vide Letter No 1125/OFV/TC Dt 4/8/2016 proposed fresh methodology for manufacture of new Amn.

Manufacture cases using Option II as per OFV letter Dt 16/03/2016.

Bullets to be manufactured as per Option II as per OFV letter Dt 16/03/2016 where Chromate Passivation on bullets be carried out by Sodium Bichromate & Sulphuric Acid (a method currently used in primer Cup & Anvil).

PPC sheet to specn No OFV/Specn/PP/102 may be used as packing metal in place of Millboard (7.62 Belted Amn).

Vide Minutes of task force meeting dated 18/10/2016, Task Force recommended PPC Sheet after conducting various trials.

COA(A) vide letter No QA13200/Blackening Dt 05/03/2017 forwarded recommendations of the Task Force:-

Fresh Amn.

Packing material - PPC Sheet

Cartridge Case Manufacture- Drilling Fire hole before final cleaning process and introduction of Neutralising by Niogen after degreasing &brightening but before passivation.

Bullet- Sodium Bichromate and Sulphuric acid solution for passivation.

Rectified Amn.

PPC Sheet to be used for packing rectified Belted Amn.

Rectified Amn to be subjected to proof firing and all procedure for release of fresh Amn to be followed.

HQ DQA(A) vide Letter Dt 01 May 2017 approved the recommendations forwarded by CQA(A).CQA(A) vide letter Dt 05/05/17 instructedtoimplementthe recommendations.The activity of backloading of Amn to OFV and rectification with Dip Cleaning method continued. 7.62mm Belted Amn re issued 520 lakhs up to 24 Sep 2019.

DGOS Minutes of Meeting dt 30 Oct 2019 on issue of blackening and remedial measures promulgated the following :-

DGQA to decide the requirement of rectification of blackened amn.

If required, backloading by 31 Dec 2019.

Way ahead to be intimated.

CQA(A) informed remedial measures.

Minutes of Collegiate Meeting of CQA(A) dt 14 Nov 2019 to find way head. Decisions :-

SQAE(A) to be involved in segregation process (12.7mm, 5.56mm & 7.62mm)

5.56mm Rectification method not yet finalized.

Method of rumbling with Cytric Acid and Rice Husk proposed.

Re-occurrence cases of 9mm observed. This should be avoided and Poly Propylene boxes to be used.

Worst affected rounds to be discarded and minimal blackened rds to be rectified.

Filling factories i.e. OFV and AFK must adhere to the QAP of AT test of Box H2A.

Re-occurrence of blackened rectified Amn to be sentenced as 'UNS'.

CQA(A)letter Dt 16 Dec 19 issued instructions as per decision taken in above meetings.CQA(A) intimated HQ DQA vide letter dt 20/01/20 :-

Recurrence cases observed in 9 mm 94 lots &12.7 mm 2 lots.

No recurrence in Belted Amn.

Vide Minutes of meeting between MGO &OFB Dt 20/01/20 OFV intimated MGO that packaging paper containing wax and moisture is main reason forblackening. Now improved version of paper quality implemented. Henceforth no blackening issues would occur.SQAE(A) vide letter Dt 13/03/20 proposed Rectification method for 5.56 mm & 7.62mm A-7.

Vibratory Bowl.

Dip cleaning method as per belted amn.

CQA(ME) vide letter Dt 26/09/20 approvedthe DipCleaningProcess for 5.56mm and A-7 Amn.Dip cleaning method approved by CQA(Met) for 5.56mm vide letter Dt 05/11/20.CQA(A) vide letter dt 23 Nov 20 intimated SQAE(A) the approval of Dip Cleaning method for 5.56mm Amn.SQAE(A) Varangaon vide letter Dt 13 Nov 2021 conveyed that 06 lot of A-7 Amn rejected at shop floor for observance of defect blackening in Aug 2021. OFV requested for rectification by Dip cleaning Method in Nov 2021.OFV & SQAE(A) carried out Process Improvement. The Chromate Passivation of empty cases as per JSS Specn 0461. SQAE(A) Varangaon letter Dt 13 Nov 21 and OFV letter Dt 11/11/21.CQA(A) vide letter Dt 18/12/21 accorded Provisionalclearancefor proposed Chromate Passivation.SQAE(A) Varangaon forwarded trial results and recommendations for Chromate Passivation vide letter and Report Dt 03 Dec 21.

CQA(Met) vide letter Dt 15/12/21 approved the rectification method "Dip Cleaning method" for A-7 Amn. Definitive test be carried out to check the efficacy of cleaning and Passivation.CQA(Met) offered comments vide letter Dt 23/12/21 on "Process Improvement Chromate Passivation & approved Chromate Passivation process for OT Lots".CQA(A) vide letter Dt 03/2/22 agreed for rectification by Dip Cleaning of 06 lots rejected at shop floor (OT Lots).

OFV and SQAE(A) suggested Sodium Sulfide test definitive as intimated through SOAE(A) letter Dt 11/04/22.CQA(Met) suggested corrosion Resistance and coating intensity test as definitive tests vide letter dt 11/04/22.CQA(A) referred the issue to CQA(Met) regarding definitive test vide letter dt 23/5/22.Status of06 rejectedlots submitted by SQAE(A) Varanqaon known vide CQA(A) letter Dt 13/5/22.CQA(Met)repliedtoCQA(A) regarding definitive test vide letter dt 31/05/22 that on OT Lots chromate passivation to be done, on 06 Rejected Lots CQA(A) to decide further course of action and on Depo returned lots as per earlier Task Force recommendations.

Regarding definitive test, CQA(Met) intimated the following through letter dt01/09/22.

For OT lots Chromate passivation is required to be carried outas per MoD orders.

Dip cleaning method is not substitute for chromate passivation while making OT lots.

For OT lots, Dip cleaning method should not continue.

OT Lots already processed using BTA treatment (Dip cleaning) may be considered for clearance or otherwise by CQA(A).

SQAE(A) Varangaon reported vide letter dated 24 Sep 2022:-

Cartgcases haveshown black/ greyish stain after chromate in silver nitrate test of chromate passivation.

OFV not following the process of chromate passivation as per JSS 0461-01.
OFV is not in agreement with results of Silver Nitrate test.
To resolve the issue at OFV, a meeting was held at CQA(A) on 26/03/2022. Decisions were conveyed through Minutes of meeting on 06 /10/22 as below :-
One standard lot of cartg case will be manufactured as per the procedure given in JSS 0461-01.
Silver Nitrate test will be carried out jointly.
Visual standards of test spots to be followed after the Silver Nitrate test should conform to the criteria given in the JSS and are to be mutually agreed between SQAE(A) and OFV.
CQA(Met) letter dated 30/09/2022 in reply to SQAE(A) Varangaon letter QAV/A7/Blackening/II dated 24 Sep 2022 asking details of Sodium Sulfide test from OFV with copy to CQA(Met) :-
Sodium Sulfide test is non- specific in nature to assess the efficacy of passivation and no literature is available.
Rectified ammunition may be subjected to corrosion resistance test and coating intensity test as give in CQA(A) specn No 0314 for 130 mm Cartgcases to assess the efficacy of passivation.
Views of NML may also be obtained.
Simultaneously SQAE(A) had also requested CQA(A) to issue directives for definitive test. CQA(A) replied that the issue already processed on file. However, the decision is yet to be taken. The likely decision is as under :-
OFV to obtain views of NML on priority.
The joint trials to be carried out for corrosion resistance test and coating intensity test as per CQA(A) 0314(c). Salt Spray Test also may be considered.
The decision for implementation of definitive test will be taken after receipt of results of (a) & (b) above.
Based on CQA(Met) letter dated 30/09/22, SQAE(A) has asked OFV vide letter dated 14/10/22 to obtain the views of NML. The views are awaited.
SQAE(A) Varangaon forwarded agenda points on 26/10/2022 also wrote on 19 Sep 22 regarding inclusion of the defect of Blackening of cartg cases in DCL. CQA(A) Comments have been processed on file. However final decision is yet to be taken.
CQA(A) comments on SQAE(A)' s suggestions regarding :-
Detailment of SQAE(A) staff for in -situ inspection of blackened amn.
Classifying the defect “Blackening of Cartg case "as major defect.
As per the direction of CQA (A) Khadki vide letter No QA13318/A-7/IND dated 08 Jan 2024, a process audit team assembled at SQAE (A) Varangaon on 16 Jan 2024, 1000 hrs.
Process Audit Team studied the entire production process of the store from input material to packaging at OFV on shop floor during 16-17 Jan 2024. Process Audit Team conducted process audit of the process "Chromate Passivation of Cartg Case" being followed at OFV. Chromate passivation process of the store is not being followed as per relevant specification JSS 0461-01: 2019. Approval for the same has not 'been obtained from competent authority by OFV.
The board opined that :-
(a) The process of Passivation followed by OFV is nonscientific by execution and the procedures do not ensure the uniformity of the desired effect on the stores due to manual operations and the execution variations by the individuals. The possibility of poor passivation cannot be ruled out while addressing the large quantity and over the extended period of operation of the procedures. It is also observed that the passivation for the primer cup is followed by a different procedure.
(b) It is observed by the user that small arms amn manufactured by OFV is found to be blackened. It is also highlighted that small arms amn portion came in contact with surface of carton boxes are found to be blackened. Also, amn lot manufactured in the year 2021 is found to have blackening effect at the point of contact with carton box used for packing of the store. 7.62mm Belted amn of vintage 2014 was also found blackened at the point of contact with the belt links and carton box.
The Board recommended that :-
(a) The process of chromate passivation may be fully automated to ensure compliance to JSS 0461-01: 2019.
(b) Alternatively, the process being followed by AFK may be studied and exercised as an intermediate method by OFV.
(c) Thecarton boxes material should be replaced as same being used in packaging of Cartg SA 9mm (Polypropylene co-polymer with 98% & 2% Anti-Static).
During spot insp in CAD from 5 – 15 Jul 2024, OFV opined that blackening on amn had occurred due to the effect of the natural phenomena of brass over a prolonged period of time and recommended the same to be considered fit for firing. However, CAD didn’t agree with the same. Ref CAD MOM 3602C/OFV/Collection/Vol-I/323/Cont/Receipt dt 02 Sep 2024.

Further a mtg was held in the office of the ADG OS (A) on the sub of blackening of SAA being mfr by OFs. Ref MOM A/18546/5.56mm INSAS/VOL -XIV/229/OS – 6C dt 27 Aug 20204.

IV. OBJECTIVES OF THE STUDY

This research intended to show the relationship between change of process and quality enhancement in terms of passivation of amn. Being specific, researcher in this thesis has concentrated on the manufacturing process in OFV. As far as DPSU (MIL / OFV) is concerned, although economic and operational decisions may be taking priority over quality control in the short-term, today's challenging times also underscore the importance of effective quality assurance. Man, material, machine and environment are changing realities adding other layers of complexity to the functions of quality assurance management. In the study the researcher has focused on the DPSU (MIL / OFV) of India because ofits major contribution to the national security and Atmanirbhar Bharat.

The researcher aimed to explore the concern that changing processes without appropriate validation is not a permanent solution to recuring quality issues in amn manufacture. The study showed that such practices are, in fact, insufficient for meeting current and future needs of quality. This study also provided recommendations for DPSU (MIL / OFV) seeking to assess and bridge the gap between where they are and where they need to be in future to accommodate with the ever changingscenario in terms of challenges on quality of its products. Furthermore, this study aimed to identify the factors influencing quality and to study the impact of validation on passivation Effectiveness.

V. STATEMENT OF PROBLEM

Based on the recommendation of one such recent process audit, OFV started using OEM chemicals for passivation of Cartridges. This was in line with what is being followed in AFK. Replacement of paper cartons by APCC was also another measure being processed & presently under implementation.

There was a need to test the effects of the change in passivation process as mentioned in the para above on the cartridges under manufacture as OT Lots. The changed process hadn't been checked for desired output on a limited pilot lot. The passivation layer of Chromium as was available earlier on the cartridges have now been replaced with the introduction of the OEM chemicals. Under these circumstances, the questions under para 48 above are relevant.

A systemic concerted effort by all agencies involved was warranted to find a long-term solution and answers to these questions. Such a measure was also relevant considering the fact that the issues of Discolouration (blackening), dezincification and corrosion are not detected during the FAI of the OT Lots but get developed few years later during the shelf life of the amn.

As part of the process as mentioned under para above, material AHSPs CQA (Met) & CQA (ME) were requested to send expert teams to study the questions as mentioned under para 48 above and to suggest feasible solutions.

VI. PURPOSE OF THE STUDY

The purpose of this study was to empirically investigate the propriety of process change that is supposedly more effective for passivation in dealing with different surface quality issues of the amn being manufactured in OFV. It applies to a specific group of amn within the range of products of OFV that displayedquality issues. It pursued the identification of various aspects and parameters that are associatedwith the surface treatment process. This may further enhance our understanding of effectiveness of surface passivation through appropriate chemicals and or processes by identifying perceived outcome that are positively related to successful quality control / assurance practices.

In order to do this the researcher decided to investigate the questions as listed under para 48 above. This study then helped in drawing few useful conclusions and recommendations which may be useful as part of the remedial and corrective measures of the surface quality issues of amn.

VII. SIGNIFICANCE OF THE STUDY

This study aimed at empirically examining the application of quality assurance by lookingattherelationshipbetweencontrol parametersandquality enhancementintermsoforganizational performance. The underlying assumption of the study was that following systematic and time-tested processes will help to maintain and enhance the quality standards of the amn being manufactured by OFV. Though the issues on blackening have been persistent for the past decade or more, little research has been done to address the issue, other than ad hoc measures without being sure of the outcome.This study has been intended to provide a contribution to the field of quality assurancewithspecialreferencetosurface treatment of amn andspecificfindingsintherelativelyuntouchedfieldoftesting and validation of passivation processes.

Testing and validation of process changes on pilot lots helps to ascertain the achievement of desired output in the products as per the principles of quality assurance.
Thisstudyattemptedtobuildonthesegeneralizationsbyprovidingadditionalandspecificunderstandingsofwhichparametersimpactparticul araspectsofdesired quality.

VIII. SCOPE OF THE STUDY

The scope of this study was to identify methods / tests to validate the changed passivation process probably by constituting a Study Group of CQA (Met), CQA (ME), User, OFV / MIL, NML and SQAE probably under the aegis of CQA (A). Further those methods and tests needed to be applied on the products to ascertain the effectiveness of the new passivation.
It was also desired to identify appropriate methods / tests to be applied on regular OT Lots in lieu of the erstwhile Silver Nitrate Test to check the efficacy of the passivation layer.
Exploration to identify substitute / additional / supplementary solutions if any may also be part of this study. Monitoring the further performance of cleaned lots for any recurrence of Blackening / Corrosion / Dezincification during the balance shelf life was also desired as applicable within the time lines of this study.
As the proof of the pudding is in eating, the ultimate verdict on all these corrective & preventive measures could be available only from the Users based on the principle that the customer is the king.

IX. LIMITATIONS OF THE STUDY

This study is limited to only OFV. One obvious limitation is the concern that the sample population studied represented a relatively small portion of all associated orgs, ests and offices. There could be a possibility that the results collected from such a sample may not be reflective of the DPSU / industry as a whole.
Another limitation common to QA studies is the possibility of reverse causality. In this study, the quality aspect of OFV is considered and the views of the Users may be biased towards their Suppliers.

1) *Discoloration, blackening, corrosion, and dezincification*

Introduction
Reliable and effective small arms ammunition is crucial in both defense and civilian applications. Factors such as discoloration, corrosion, and material degradation can significantly impact ammunition performance, compromising safety and usability. This chapter examines existing research, focusing on the root causes, mechanisms, and mitigation strategies for these degradation phenomena (Davis, J. R. (2000). Corrosion: Understanding the Basics. ASM International.).

2) *Material Composition and Properties of Small Arms Ammunition*

Brass, an alloy of copper and zinc, is the preferred material for small arms ammunition due to its desirable properties. While it offers good corrosion resistance, it is susceptible to dezincification and other forms of corrosion. Cartridge brass, a common type, provides a balance of strength and ductility but is vulnerable to degradation in aggressive environments. Manufacturing processes, particularly cold working, can influence the material's resistance to corrosion, including stress corrosion cracking. Alloying additions, such as tin, can improve resistance to dezincification, as demonstrated in long-term testing (Fontana, M. G. (2005). Corrosion Engineering (3rd ed.). McGraw-Hill.).
Steel, often used in projectile cores, is prone to rusting in the presence of moisture. Modern advancements include the use of galvanized steel to enhance durability. Copper is commonly used for bullet jackets, while nickel alloys offer improved resistance to blackening and wear. (ASM International. (2001). Metals Handbook, Volume 13: Corrosion (9th ed.). ASM International.).

3) *Discoloration and Blackening*

Corrosion in ammunition primarily occurs through electrochemical processes. Metals commonly used in ammunition components, including brass, steel, and copper, are susceptible to oxidation when exposed to oxygen and moisture. These electrochemical reactions result in the formation of metal oxides or hydroxides. Brass casings, for example, are vulnerable to dezincification, a process where zinc is selectively leached from the alloy, leaving behind a porous and brittle copper structure. This significantly impacts the structural integrity and functionality of the brass casing, particularly in saline or acidic environments (Brooks, C. R. (1992). Heat Treatment, Structure, and Properties of Nonferrous Alloys. ASM International.).Discoloration and blackening are surface-level indications of oxidation and tarnishing.

While they may not immediately compromise mechanical integrity, they signal underlying corrosion processes that can worsen over time. These phenomena are primarily caused by reactions involving copper and zinc. Copper, for example, forms copper oxide in humid environments, leading to darkening. Additionally, sulfur-rich pollutants can accelerate the rate of blackening. Industrial environments with high levels of sulfur dioxide have been shown to significantly increase tarnishing rates in brass alloys (International Journal of Materials Research (2023). Corrosion resistance of brass alloys in ammunition casings: A review. International Journal of Materials Research, 114(3), 203–214.).

4) Factors Influencing Degradation

High humidity significantly impacts ammunition deterioration. Temperature fluctuations intensify moisture condensation, accelerating corrosion. Coastal areas, with salt-laden air, expose ammunition to Chloride ions, which aggressively promote pitting and crevice corrosion. These ions can penetrate protective layers, causing localized damage. Contaminants such as grease and organic residues act as catalysts for corrosion, trapping moisture or providing nutrients for microbial growth (Fontana, M. G. (2005). Corrosion Engineering (3rd ed.). McGraw-Hill.).

5) Preventive Measures

Nickel electroplating or applying clear coatings effectively prevents discoloration. Corrosion compromises ammunition's structural integrity and functionality. Common corrosion mechanisms include: Uniform Corrosion: Brass corrodes evenly in neutral or mildly acidic environments. Pitting Corrosion: Localized attacks create pits, leading to mechanical failure. Stress Corrosion Cracking (SCC): This occurs under tensile stress in the presence of Chlorides. Advanced surface treatments, like electroless Nickel plating, have shown promise in mitigating pitting corrosion (Davis, J. R. (2000). Corrosion: Understanding the Basics. ASM International.).

6) Dezincification of Brass

Dezincification, a type of selective leaching, removes zinc, leaving a porous copper-rich structure. This significantly weakens the material. Frequently observed in Chloride-rich environments, dezincification is accelerated by acidic conditions. Studies indicate a reduction in mechanical properties by up to 30% in dezincified brass samples. Tin-bearing brass alloys and cathodic protection methods reduce susceptibility to dezincification(Shreir, L. L., Jarman, R. A., & Burstein, G. T. (1994). Corrosion: Metal/Environment Reactions (Vol. 1). Butterworth-Heinemann.).

7) Testing and Evaluation Techniques

To ensure ammunition durability and safety, rigorous testing procedures are used. Electrochemical Testing: Potentiodynamic polarization provides insights into corrosion rates and mechanisms. Microscopic Analysis: Scanning Electron Microscopy (SEM) combined with Energy Dispersive Spectroscopy (EDS) aids in analyzing corrosion products and dezincification zones. Accelerated Aging Tests: Salt spray tests simulate long-term exposure conditions (ASM International. (2001). ASM Handbook, Volume 5: Surface Engineering. ASM International.).

8) Preventive and Mitigation Strategies

Research highlights the importance of a combined approach to minimize deterioration. Material Advancements: Focus on developing alloys that resist dezincification. Surface Treatments: Apply polymer-based coatings to prevent tarnishing and corrosion. Storage Practices: Controlled environments with desiccants minimize exposure to humidity and pollutants. Routine Maintenance: Regular cleaning and inspection reduce surface oxidation and Chloride buildup. Emerging Technologies: Research on nanostructured coatings and hybrid alloys is ongoing. VpCI-based coatings(Vapor-phase Corrosion Inhibitor coatings) are widely recommended for their ability to create a protective barrier, preventing oxygen and moisture from contacting metal surfaces (Baboian, R. (2005). Corrosion Tests and Standards: Application and Interpretation. ASTM International.).

9) Environmental Factors

Environmental conditions significantly influence ammunition performance and degradation rates. Climatic Impact: Brass samples in tropical climates showed corrosion rates up to 50% higher than those in temperate climates. Storage methods such as nitrogen-purged environments have been shown to extend ammunition shelf life by up to 30%. Maintaining optimal storage conditions is crucial for corrosion prevention. Techniques include dehumidification, using Silica Gel packets, and utilizing climate-controlled storage facilities (Corrosion Science (2023).

Mechanisms and mitigation of dezincification in brass alloys. Corrosion Science, 214, 112–128. https://doi.org/10.1016/j.corsci.2023.112128).

X. CASE STUDIES AND OBSERVATIONS

In tropical regions, a military encountered severe corrosion in cartridge cases. By employing vapor-phase corrosion inhibitor (VpCI) papers, they significantly reduced corrosion-related failures and achieved substantial annual cost savings (Cortec Corporation, 2024). North American Storage Facilities. Research conducted in controlled storage environments within North America demonstrated the effectiveness of climate control systems in minimizing corrosion and discoloration issues (Eva-Dry, 2024). Industrial Experiments. Experimental studies conducted in humid and saline environments have provided valuable insights into the effectiveness of various coatings and inhibitors in reducing dezincification and corrosion (Defense and Munitions, 2024).

A. Justification of Research Gap

The evolution of operations management within the ammunition manufacturing sector has been significantly influenced by technological advancements, shifting global defense requirements, and the continuous pursuit of efficiency, quality, and safety. From its early reliance on manual labor, the industry has consistently adapted to meet the demands of modern warfare by embracing mass production and modern automation techniques. Looking ahead, emerging technologies such as 3D printing and Industry 4.0 are poised to further revolutionize the field, offering new avenues for improving production processes and ensuring the safety and reliability of ammunition products.

The challenges associated with discoloration, blackening, corrosion, and dezincification in small arms ammunition are multifaceted but can be effectively addressed through existing and emerging technologies. Successful mitigation strategies require a combination of material innovation, environmental control, and adherence to best practices. Continued research in this area will further enhance ammunition safety and reliability. This review highlights significant advancements in our understanding of the degradation of small arms ammunition, while emphasizing the need for innovative materials, predictive testing methodologies, and comprehensive field studies. Addressing these knowledge gaps will enhance the durability, safety, and reliability of ammunition, particularly in demanding operational environments.

B. Research Gap

Based on the recommendation of one recent process audit, OFV has now started using OEM chemicals for passivation of Cartridges. This is in line with what is being followed in AFK. Replacement of paper cartons by APCC is also another measure being processed & presently under pre adoption tests.

There is a need to test the effects of the change in passivation process as mentioned in para 2 above on the cartridges under manufacture as OT Lots. The changed process hasn't been checked for desired output on a limited pilot lot. The passivation layer of Chromium as was available earlier on the cartridges have now been replaced with the introduction of the OEM chemicals. Under these circumstances, the following questions are relevant.

What is the new layer formed on the cartridges while using the OEM chemicals / changed process ?

What are the tests applicable to check its effectiveness in lieu of Silver Nitrate test as was applicable for earlier Chromium layer ?

What all other tests such as ISAT etc are recommended to be carried out to ascertain that the changed process will prevent discolouration (Blackening) during the entire assured shelf life of the amn ?

What all one time tests & checks may be recommended to ascertain such efficacy ?

What all tests & checks may be recommended to ascertain such efficacy during FAI of OT lots ?

Is there scope to measure the thickness & evenness of the passivation layer by any means ?

Can we implement corrosion resistance test, salt spray test and coating intensity test ?

Keeping aside the recommendation of the Process Audit, what is the difference if OFV has gone back to the process as was existing prior to adoption of Chromate Passivation ?

How are the reasons cited at the time of Chromate passivation for junking the OEM process not relevant now ?

The proposed study, titled "An Investigation into Discoloration, Blackening, Dezincification, and Corrosion of 7.62 mm Ball Ammunition Produced at Ordnance Factory Varangaon and its Operational Management," is well-supported by existing research. Data in support of the issue is tabulated in the appendix attached at the end of this Chapter. Ammunition degradation, encompassing discoloration, blackening, dezincification, and corrosion, is widely acknowledged as a significant concern impacting safety, reliability, and performance.

Research emphasizes the influence of material composition, environmental conditions, and storage practices on ammunition component degradation. While brass, steel, and copper are commonly used in ammunition manufacturing, they are susceptible to corrosion and stress-related failures, particularly in environments with high humidity or chloride levels. Preventive measures such as nickel plating, polymer coatings, advanced storage techniques, and rigorous testing protocols have demonstrated potential in mitigating these issues.

XI. HYPOTHESIS

1) H1 : Validation of the changed passivation process is mandatory to confirm its effectiveness in preventing the occurrence of Blackening / Corrosion / Dezincification in 7.62 mm Cartgs of OFV in future.
2) H2: New testing methods for OT Lots are essential to check the effectiveness of the new passivation layer in preventing the occurrence of Blackening / Corrosion / Dezincification in 7.62 mm Cartgs of OFV in future.
3) H3: There is a possibility of the availability of other solutions (substitute / additional / supplementary) to arrest the occurrence of Blackening / Corrosion / Dezincification in 7.62 mm Cartgs of OFV.
4) H4: Recurrence of Blackening / Corrosion / Dezincification in 7.62 mm Cartgs which have been subjected to Dip Cleaning once before during their shelf life is not expected.
5) H5: The process of corrective actions on already affected amn by OFV are up to the satisfaction of all affected Users.

Limitations of the study are as follows:

- The study is limited to the products of OFV.
- The study addressed the performance of the products of OFV with regard to their specific quality issues only as the crucial factor in overall long-term sustenance of the products.
- The study is based on information collected from OFV, SQAE(A) Varangaon / DGQA and their records.

XII. RESEARCH METHODOLOGY

The complexity of the problem necessitates a mixed-methods approach, integrating quantitative and qualitative techniques to achieve a holistic understanding.
Quantitative Methods: Data Collection: Gathering production data from OFV, including rejection rates, material specifications, and process parameters. Conducting laboratory tests to analyze chemical reactions leading to dezincification and corrosion. Data Analysis: Using statistical software to identify correlations and root causes. Modeling predictive scenarios to assess the impact of proposed interventions.
Qualitative Methods: Interviews and Focus Groups: Engaging with production staff and quality inspectors to understand operational challenges. Process Mapping: Documenting workflows to identify inefficiencies or potential contamination points.
The mixed-methods approach ensures that technical findings are complemented by practical insights, enhancing the relevance and applicability of the study.
Data tabulation of few affected Lots

SN	AMN	Nomenclature	Lot No	Qty	Date Affected
1	32A	S.A. 7.62mm Ball Belted Tracer	Various lots of vintage 2002, 2006, 2007, 2010 to 2014	3493146 (152,360 MTs)	10 Jun 2024
2	32/32A	S.A. 7.62mm Ball Belted Tracer	Various lots of vintage 1992 to 2015, 2018 & 2018	78491413 (3423.561 MTs)	10-Nov-14
			Various lots of vintage 2000 to 2012	1459110 (63.642 MTs)	

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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3	TBA	S.A. 7.62mm Ball Cart. B-32 API	12 Nos	24480	28th May 2018
4	27A	S.A. 5.56mm Ball Carts INSAS	2018-08-113-OFV 2018-06-117-OFV 2018-05-112-OFV 2018-06-124-OFV 2018-05-110-OFV	1794085 (33.639 MTs)	Nov-18
5	27A	S.A. 5.56mm Ball Carts INSAS	2018-04-102-OFV 2018-04-100-OFV 2018-04-103-OFV 2018-05-104-OFV 2018-05-105-OFV 2018-05-108-OFV 2018-05-109-OFV 2018-05-114-OFV 2018-06-115-OFV 2018-06-115-DFV 2018-06-130-OFV 2018-07-132-OFV	3601085 (67.520 MTs)	Mar-19
6	78A	S.A. 12.7mm Bullet Carts B32 API	Vintage 2017	176199 (14.139 MT)	27-May-24
7	79A	S.A. 12.7mm Bullet Carts B32 APIT	Vintage 2017	193231 (37.437 MT)	27-May-24
8	50G	Cart. 7.62mm Ball A-7 IND	2018-11-19-012A-OFV 2018-11-15-011A-OFV 2018-12-10-022A-OFV 2018-12-07-021A-OFV 2018-11-20-013A-OFV 2018-11-29-017A-OFV 2018-11-24-015A-OFV 2018-12-24-028A-OFV 2018-10-22-006A-OFV 2018-12-06-020A-OFV 2019-01-17-039A-OFV	1779586 (44.490 MTs)	Jul-19
9	50G	Carts 7.62mm Ball A-7 IND	2020/08/16/A60/OFV 2020/12/A84/OFV 2020/12/A80/OFV 2020/08/20/A51/OFV	751047 (18.776 MTs)	Feb-22
10	50G	Carts 7.62mm Ball A-7 IND	2021/01/A01/OFV 2021/01/A04/OFV 2020/12/A85/OFV 2021/01/A04/OFV	527384 (13.184 MTs)	Jun-21

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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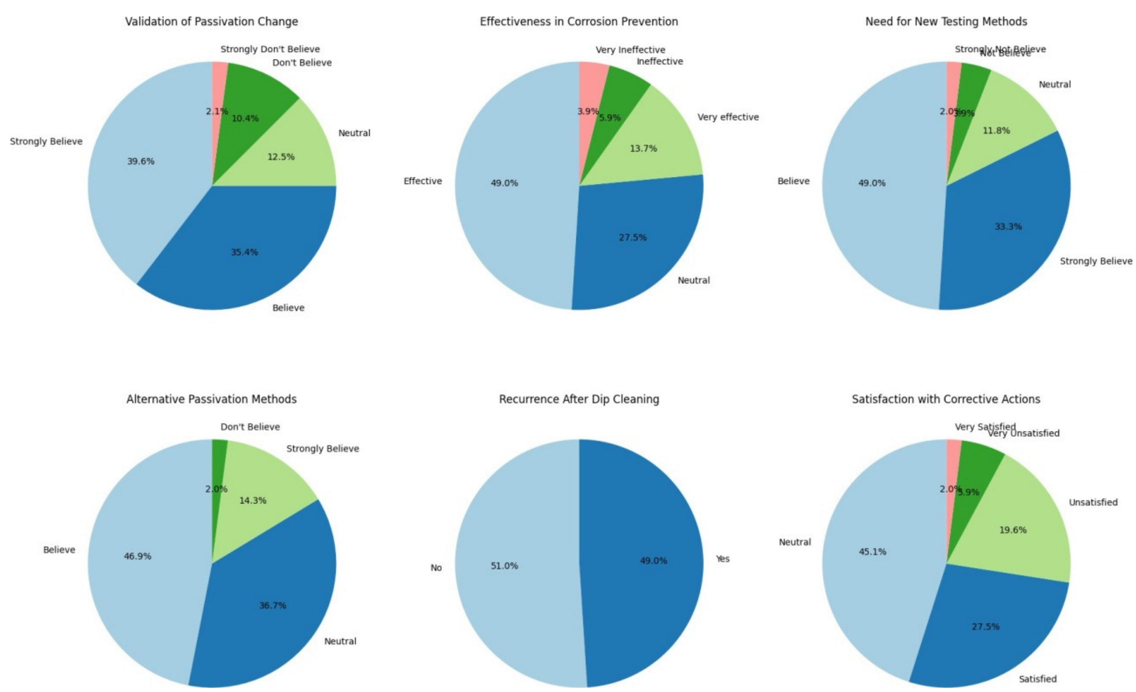
11	50G	Carts 7.62mm Ball A-7 IND	2020-07-30-A48-OFV	45360 (1.131 MTE)	Jul-22
12	50G	Carts 7.62mm Ball A-7 IND	2021/12/29/A73/OFV 2021/12/22/A71/OFV 2022/01/05/A01/OFV 2022/01/23/A11/OFV	720 263161 298098 562699 (14.067 MTS)	Sep-22
13	50G	Carts 7.62mm Ball A-7 IND	2022/01/09/A03/OFV 2022/01/11/A04/OFV 2022/01/18/A08/OFV	297433 297428 295426 (22.275 MTs)	Feb-23
14	27A	Carts SA 5.56mm Ball INSAS	53 OFV 07-10-2020 60 OFV 04-09-2020	953600 (17.880 MTs)	20-Apr-23
15	50G	Carts SA 7.62mm Ball MK-II	2021-12-09-A66-OFV	100000 (2.499 MT)	

XIII. DATA ANALYSIS AND INTERPRETATION



A. *Validation of Passivation Change*

When asked about the revised passivation process, survey participants generally expressed positive views. Specifically, 39.6% felt the changes were effective, and an additional 12.5% held strong convictions in their validity. However, a substantial 27.1% remained undecided. Opposition was present, with 13.5% expressing disbelief and 7.3% strongly disagreeing with the validation. Overall, the data suggests a largely positive reception, though a considerable proportion held reservations.
Effectiveness of corrosion prevention

Regarding the effectiveness of current corrosion prevention efforts, the survey revealed a similar trend. A plurality, 39.6%, found the methods effective, while 13.7% considered them very effective. A neutral stance was adopted by 27.1% of respondents. Conversely, 7.3% found the methods ineffective, and 12.3% deemed them very ineffective. This distribution indicates a generally favorable, albeit nuanced, perception of the current corrosion prevention strategies, with a clear need to address the concerns of those who perceive them as inadequate.

B. Need for New Testing Methods

Participants overwhelmingly expressed a desire for updated testing procedures. A significant portion, 43.7%, felt strongly that novel testing methods were essential, while an additional 27.1% recognized the necessity for modifications. A smaller group, 13.5%, held no firm opinion. Conversely, a minority, totaling 15.7% (11.5% plus 4.2%), expressed resistance to change. The survey results clearly demonstrate a strong inclination towards the adoption of more sophisticated and dependable testing protocols to bolster quality control.

C. Alternative Passivation Methods

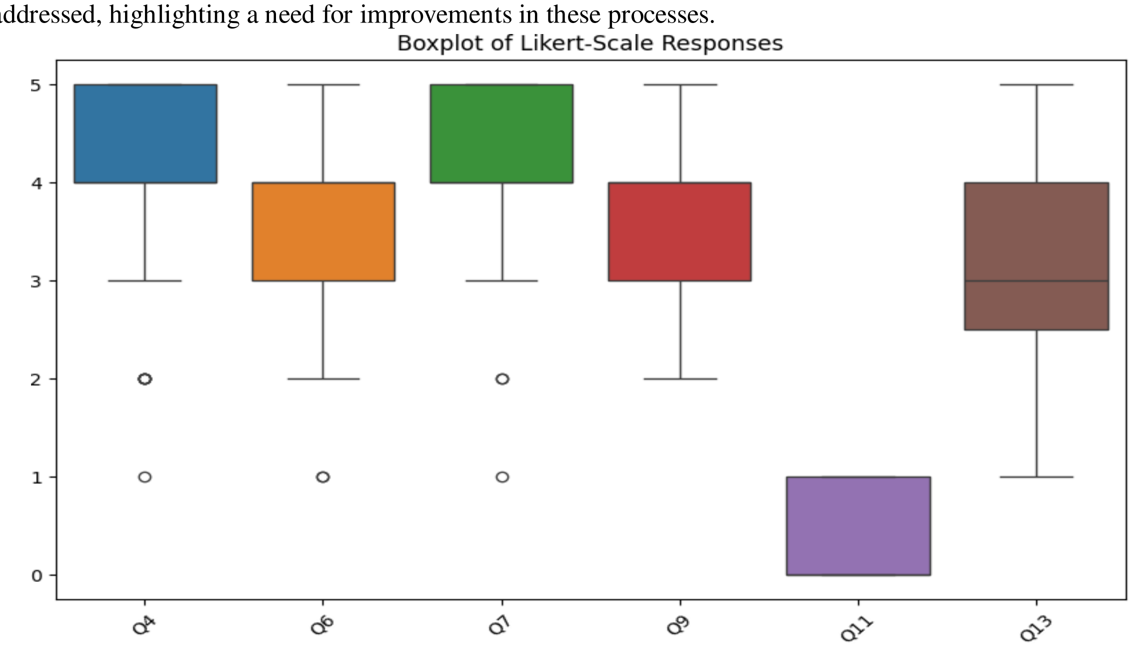
Opinions regarding the investigation of alternative passivation techniques were varied, though leaning slightly positive. Approximately 34.7% of participants favored exploring new methods, with an additional 9.4% expressing strong support. However, a considerable 46.9% remained undecided, revealing a lack of clear opinion or information. Conversely, 9% (6.3% plus 2.7%) expressed opposition. This data indicates a moderate level of interest in alternative passivation approaches, but also highlights a significant portion of respondents who are either unsure or uninformed.

Recurrence After Dip Cleaning

When considering the effectiveness of dip cleaning in preventing recurring issues, the results were nearly evenly split. A slight majority, 52.9%, reported no recurrence of problems, suggesting some level of success. However, a substantial 47.1% experienced recurring issues, indicating that the dip cleaning process, or subsequent procedures, may require refinement. This near-equal distribution suggests that while dip cleaning is often effective, inconsistencies can lead to recurring defects, necessitating further examination.

D. Satisfaction with Corrective Actions

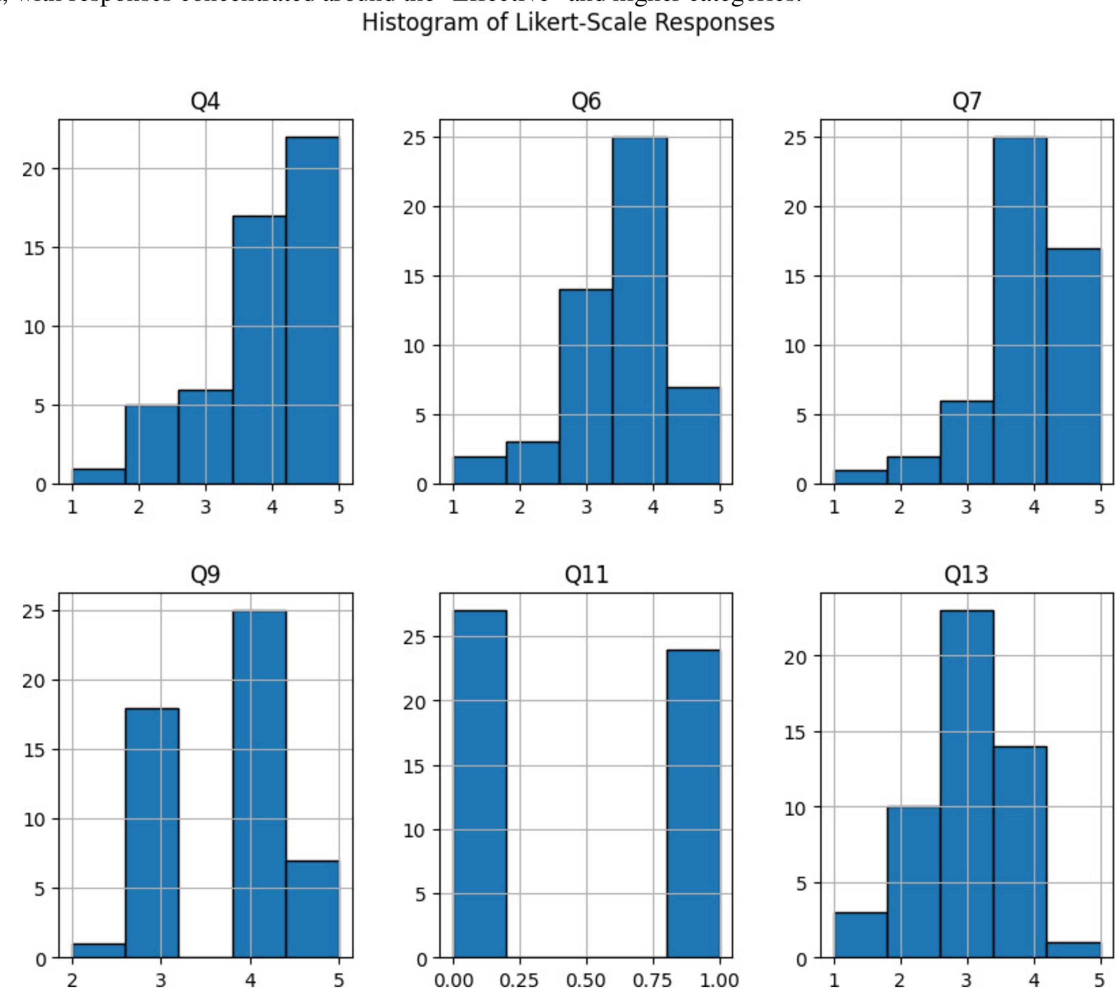
The feedback on satisfaction with corrective actions revealed a blend of positive and negative responses. A combined 44.8% (27.1% plus 17.7%) of respondents expressed satisfaction, demonstrating confidence in the implemented solutions. However, a significant 41.7% (26.1% plus 15.6%) were dissatisfied, and 13.5% remained neutral. This substantial level of dissatisfaction indicates that while some corrective measures are successful, a considerable proportion of respondents feel their concerns are not being adequately addressed, highlighting a need for improvements in these processes.



To understand the viewpoints of respondents concerning corrosion prevention strategies for 7.62 mm cartridges at OFV, Likert-scale data was analyzed. The statistical summary, based on 51 participant responses, included calculations of central tendency and dispersion, such as averages, variability, and distribution patterns.

Regarding the necessity of validating the revised passivation process (Q4), respondents demonstrated a strong consensus. The average response, 4.06 on a 5-point scale, and the most frequent response, "Strongly Believe," indicated a firm belief in the importance of validation. While some variation existed, as shown by a standard deviation of 1.07, the overall trend leaned heavily towards strong agreement.

When assessing the perceived effectiveness of the modified passivation procedure in preventing corrosion (Q6), respondents generally expressed positive views. The average rating of 3.63, combined with the most common response of "Effective," suggested that participants largely perceived the change as successful. With a standard deviation of 0.94, the data indicated a reasonable level of agreement, with responses concentrated around the "Effective" and higher categories.



When asked about the necessity of novel testing protocols for assessing the revised passivation process (Q7), participants showed strong agreement. The average response of 4.08, combined with the most frequent response of "Believe," indicated a firm conviction in the need for new testing methods. This high level of consensus was further supported by the low variability in responses, as indicated by a standard deviation of 0.89.

Regarding the perceived existence of alternative passivation approaches (Q9), respondents generally believed in their availability. The average rating of 3.75, with the most common response of "Believe," demonstrated a widespread acceptance of the potential for alternative methods. The relatively low standard deviation of 0.72 indicated a strong level of agreement among participants.

The binary question regarding the sufficiency of the current passivation process post-dip cleaning (Q11) revealed a near-even split. The average score of 0.47, with the most frequent response being "No," indicated that approximately half of the respondents believed the current process was inadequate.

The standard deviation of 0.50 reflected the binary nature of the responses and the divided opinion.

When assessing satisfaction with corrective measures for affected cartridges (Q13), respondents generally expressed neutrality. The average rating of 3.00, with the most common response being "Neutral," indicated a lack of strong positive or negative sentiment. The standard deviation of 0.89 suggested some variability in satisfaction levels.

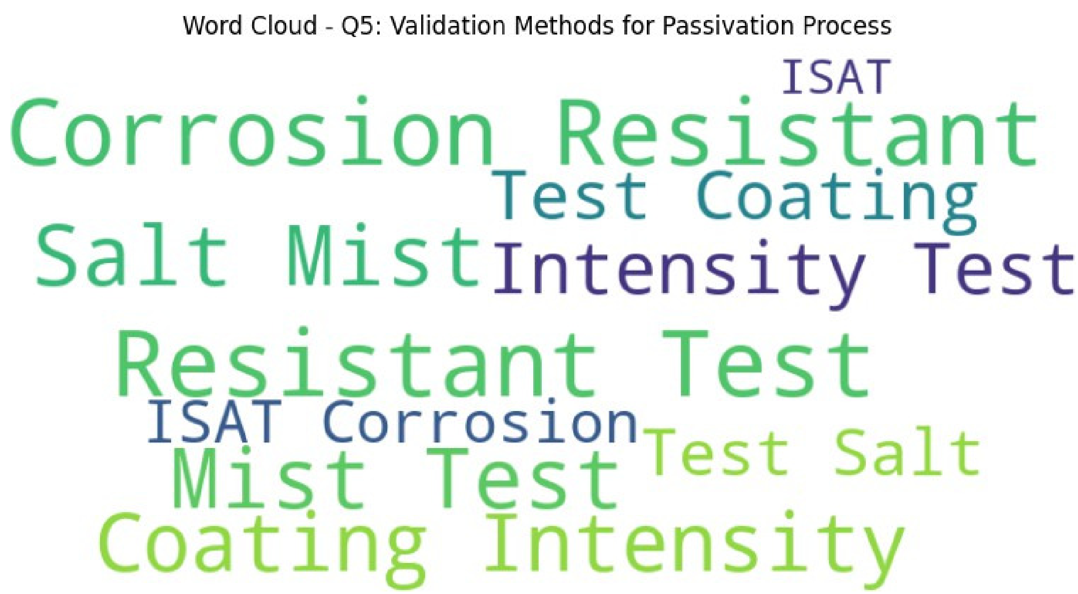
In essence, the data indicated a strong endorsement for validating and testing the new passivation process, with general agreement on its effectiveness. However, opinions were divided on the sufficiency of the current process after dip cleaning, and overall satisfaction with corrective measures was neutral. These findings underscore the need for further validation and potential exploration of alternative methods to enhance corrosion prevention in 7.62 mm cartridges.

E. Hypothesis testing

The primary objective of the initial hypothesis (H1) was to ascertain the perceived value of confirming the modified passivation procedure. Essentially, H1 proposed that participants would demonstrate a substantial inclination towards validating the updated passivation method, ensuring its efficacy in preventing detrimental effects like discoloration, rust, or zinc loss in 7.62 mm ammunition. To analyze this, a single-sample t-test was employed to assess if responses leaned significantly towards validation. The analysis revealed an average response of 4.06 on a 5-point scale, which significantly exceeded the neutral value of 3.0. This outcome indicates a strong consensus among respondents regarding the necessity of validating the novel passivation technique. Therefore, H1 is supported, confirming a clear preference for validation among the surveyed individuals.

Furthermore, to investigate whether respondents' professional tenure influenced their views on validation, a Chi-Square test of independence was conducted. The resulting Chi-Square statistic was $\chi^2 = 146.555$, with a corresponding p-value of 0.125. As this p-value exceeded the standard threshold of 0.05, it suggests that no significant association exists between respondents' experience and their opinions on validation. In simpler terms, regardless of their level of expertise, participants consistently advocated for validating the new passivation process. This observation reinforces the idea that validation is viewed as a universally important step, independent of the respondents' professional background or experience.

In summary, the statistical analyses performed confirm that the validation of the revised passivation procedure is widely considered crucial by respondents, regardless of their experience. The single-sample t-test verified a significant preference for validation, while the Chi-Square test demonstrated that this preference remained consistent across various experience levels. These findings emphasize the vital role of validation in guaranteeing the effectiveness of the new passivation strategy and highlight the continued importance of thorough testing and assessment in corrosion prevention methodologies.Hypothesis Testing: H3:Availability of Other Solutions



To investigate if participants shared a common perspective on the presence of substitute methods for the existing procedures, the following statistical inquiry was established:

Null Hypothesis (H_0): Participants do not demonstrate a unified view regarding the existence of alternative solutions.

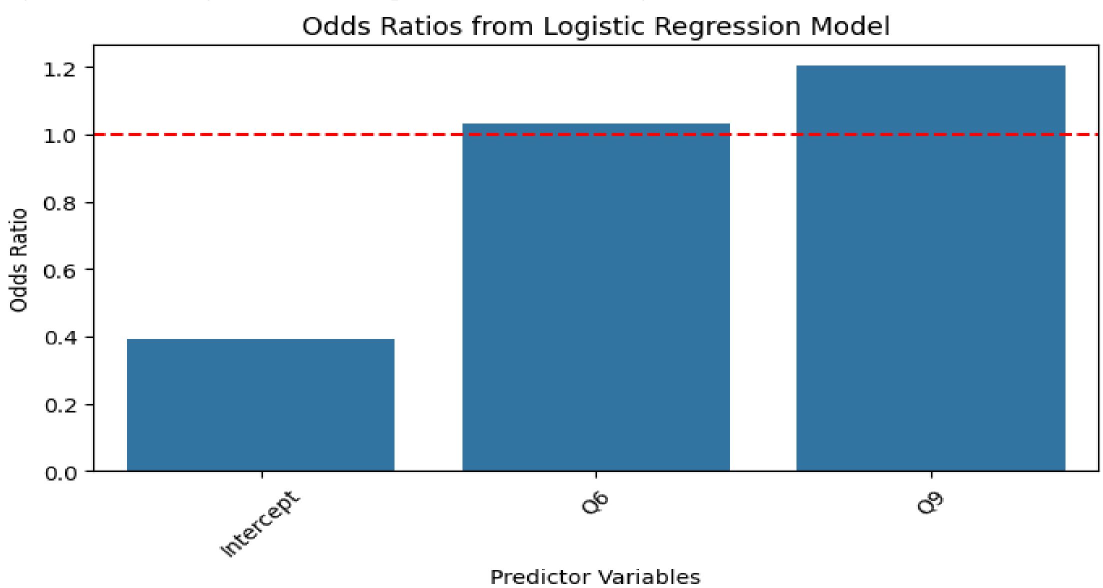
Alternative Hypothesis (H_1): Participants exhibit a notable consensus regarding the existence of alternative solutions.
A Chi-Square test for independence was employed to analyze the collected data, determining whether the response patterns deviated significantly from random distribution. This analysis aimed to identify any consistent trends or agreement among participants.
The results of the Chi-Square test were as follows:
Chi-square (χ^2) = 87.480
p-value = 0.721
The substantial p-value (0.721), surpassing the standard significance threshold ($\alpha = 0.05$), necessitated the retention of the null hypothesis. This finding indicates that there was no statistically significant agreement among respondents concerning the availability of alternative solutions.

The "Alternative Passivation Methods" pie chart visually represented the distribution of opinions, revealing a varied range of responses:

Affirmative (34.7%)
Strongly Affirmative (6.9%)
Undecided (46.5%)
Negative (11.9%)
The prominent percentage of undecided responses (46.5%) suggested a considerable degree of ambiguity or insufficient awareness regarding alternative methodologies among the participants. While a subset of participants did express belief in the presence of alternatives (a combined 41.6% for affirmative and strongly affirmative), the lack of a clear consensus corroborated the statistical outcome.
In summary, the Chi-Square test demonstrated a lack of significant agreement regarding the availability of alternative solutions, which aligned with the diverse and inconclusive feedback observed in the survey results. This outcome underscores the necessity for further investigation and enhanced communication regarding potential alternatives to current processes, aiming to address the knowledge gaps identified among stakeholders.

1) H4: Effectiveness of Dip Cleaning

Hypothesis H4 aimed to assess how well dip cleaning prevents corrosion-related problems from reappearing in cartridges. To examine this, a blend of statistical techniques was utilized, specifically a paired t-test and logistic regression. The paired t-test, given the availability of before-and-after cleaning data, was intended to measure if the cleaning procedure significantly reduced corrosion. However, the analysis showed that dip cleaning had no substantial effect. The resulting p-value was greater than the standard 0.05 limit, implying that the cleaning method did not produce a notable change in corrosion levels.



International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Furthermore, logistic regression was performed to determine if cleaning method effectiveness (Q6) and belief in alternative passivation approaches (Q9) could predict the probability of corrosion reappearance. The logistic regression model demonstrated that neither cleaning efficacy nor belief in alternative methods were significant predictors of recurrence. The odds ratios for both predictors were near 1, indicating a negligible influence on the likelihood of recurrence. Additionally, the model's pseudo R-squared value was extremely low (0.003), suggesting that the predictors accounted for very little of the variation in recurrence outcomes.
To summarize, analyses using both the paired t-test and logistic regression revealed that the current dip cleaning method does not demonstrably prevent corrosion recurrence. This suggests that other or supplemental strategies are likely needed for effective problem resolution. The findings emphasize the need to investigate other potential factors contributing to corrosion reappearance and to explore more effective cleaning or passivation techniques

2) *H5: Satisfaction with Corrective Actions*

Hypothesis H5 focused on gauging respondents' contentment with the steps taken to address issues like discoloration, corrosion, or zinc loss in cartridges. To achieve this, descriptive statistics and the Kruskal-Wallis test were employed. Descriptive statistics showed an average satisfaction score (Q13) of 3.0 on a 5-point Likert scale, indicating a generally neutral to somewhat satisfied perception. The distribution of satisfaction scores varied, encompassing responses from "Very Dissatisfied" to "Very Satisfied."
The Kruskal-Wallis test was conducted to determine if satisfaction levels differed significantly across various roles or titles (Q5). The results indicated no notable variations in satisfaction across roles, as the p-value (0.584) exceeded the 0.05 threshold. This suggests that satisfaction with corrective actions was relatively consistent across different job functions, implying that the corrective measures were perceived similarly regardless of the respondent's position.
Furthermore, ordinal regression was used to identify factors predicting satisfaction, using the efficacy of the passivation method (Q6) and belief in alternative approaches (Q9) as independent variables. The analysis demonstrated that the passivation process's effectiveness (Q6) was a significant predictor of satisfaction, with greater effectiveness correlating with higher satisfaction. Conversely, belief in alternative methods (Q9) did not significantly influence satisfaction levels.
In conclusion, the results indicate that while overall satisfaction with corrective actions was moderate, the passivation method's effectiveness significantly influenced respondents' satisfaction. The consistency of satisfaction across roles suggests that the corrective actions were perceived similarly, but there is potential for improvement, especially by focusing on enhancing the passivation process's effectiveness. These findings highlight the importance of refining corrective measures to increase stakeholder satisfaction.

Word Cloud - Q14: Other Suggestions/Recommendations

XIV. FINDINGS

Regardless of experience, those surveyed consistently emphasized the necessity of validating the revised passivation procedure.
Opinions varied considerably regarding the existence of viable substitutes for cartridge surface passivation.
The current dip cleaning method showed little impact on preventing corrosion from reappearing.
The overall level of contentment with the implemented corrective measures was average.

XV. CONCLUSION

This study investigated critical facets of the revised passivation process validation, the efficacy of dip cleaning, and the contentment with implemented corrective measures. Utilizing a range of statistical techniques, including chi-square tests, logistic regression, paired t-tests, and ordinal regression, several key findings were identified.

Initially, the validation of the altered passivation procedure (H1) revealed no notable correlation between respondent experience and their assessment of the validation. This implies that experience did not impact perceptions of the process's efficacy. Secondly, the dip cleaning's effectiveness (H4) was statistically insignificant, as both the paired t-test and logistic regression demonstrated that it did not substantially mitigate corrosion recurrence. This underscores the necessity to investigate alternative or complementary cleaning approaches to better address corrosion issues.

Concerning satisfaction with corrective actions (H5), the analysis indicated that although overall contentment was average, the passivation process's effectiveness significantly predicted increased satisfaction. However, satisfaction levels remained consistent across different roles, suggesting a shared perception of the corrective measures. These results point to the potential for enhanced overall satisfaction among stakeholders by improving the passivation process's effectiveness.

In conclusion, the hypothesis testing outcomes emphasize the significance of refining the passivation process and seeking alternative solutions to boost both effectiveness and satisfaction. While some hypotheses did not yield significant outcomes, they offer valuable insights into areas demanding further study and potential enhancements. Subsequent research could concentrate on pinpointing additional factors influencing corrosion recurrence and satisfaction, and also on evaluating novel methods to improve the general efficacy of corrective actions.

XVI. RECOMMENDATIONS

To address the issues uncovered in this research regarding the passivation process, dip cleaning, and corrective actions, several recommendations are presented. These suggestions aim to enhance the efficacy of corrosion prevention and improve stakeholder contentment.

Refine the Passivation Protocol: Given the significant impact of the passivation process's efficacy on satisfaction, optimizing this procedure is essential. Further research and development to improve passivation techniques could yield better outcomes in preventing discoloration, corrosion, and dezincification. Regular validation and testing of the passivation process should be prioritized to ensure its ongoing effectiveness.

Explore Alternative Cleaning Strategies: The findings indicated that dip cleaning did not substantially reduce corrosion recurrence. Therefore, investigating and evaluating alternative cleaning methods that may provide superior results is recommended. Integrating advanced cleaning technologies or combining multiple cleaning techniques could potentially enhance the overall effectiveness of corrosion prevention.

Establish Ongoing Monitoring and Feedback Systems: Implementing a system for continuous monitoring and stakeholder feedback can facilitate the identification of improvement areas in real-time. Regular surveys and feedback sessions can offer valuable insights into the efficacy of corrective actions and highlight any emerging issues requiring immediate attention.

Strengthen Training and Educational Initiatives: Providing comprehensive training and educational programs for all stakeholders involved in passivation and cleaning processes can lead to improved implementation and comprehension of procedures. Ensuring all personnel are well-versed in the latest techniques and best practices can contribute to more consistent and effective outcomes.

Investigate Additional Variables Affecting Corrosion: While this study focused on specific factors, examining other potential variables that may influence corrosion recurrence is recommended. Factors such as environmental conditions, material quality, and handling procedures should be analyzed to develop a more comprehensive approach to corrosion prevention.

Promote Interdepartmental and Expert Collaboration: Encouraging collaboration between various departments and external specialists can foster innovation and the exchange of best practices. Collaborative efforts can lead to the development of new solutions and enhancements to existing processes, ultimately improving the overall effectiveness of corrosion prevention measures.

Implementing these recommendations can enable more effective resolution of the identified issues, resulting in improved corrosion prevention outcomes and greater stakeholder satisfaction. Continuous improvement and adaptation to new challenges will be crucial for achieving sustained success in this area.

Ethical Declaration

There are no ethical statements to declare. Informed consent from research participants has been obtained.

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[11] CQA(Met) letter No CQA(M)/QA-2/7.62mm/AmnNol-09 dated 11 Apr 2022.
[12] CQA(Met) letter No CQA(M)/QA-2/7.62mm/AmnNol-09 dated 15 Dec 2021.
[13] HQ DQA(A) letter No 95344/12.7 & 7.62mm Amn/DGQA/Arm-5 dated 01 May 2017.
[14] CAD Pulgaon letter No 3602C/GenNol-l/335/Cont/Receipt dt 13 Nov 2021.
[15] CAD Pulgaon letter No 3602C/GenNol-lll/159/Cont/Receipt dt 17 Dec 2021.
[16] CAD Pulgaon letter No 3602C/GenNol-lll/170/Cont/Receipt dt 29 Jan 2022.
[17] CAD Pulgaon letter No 3602C/OFVNol-l/26/Cont/Receipt dt 24 Jun 2022.
[18] CAD Pulgaon letter No 3602C/OFVNol-I/45/Cont/Receipt dt 04 Aug 2022.
[19] CAD Pulgaon letter No 3602C/OFVVol-/48/Cont/Receipt dt 06 Sep 2022.
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[21] Minutes on Defect Investigation of AMK-50G, Carts SA 7.62mm Ball A-7 Mk-II Amn (qty 562699) at CAD Pulgaon from 20 Oct 2022 to 22 Oct 2022.
[22] In-Situ Joint Investigation Report of Blackened Ammunition of Cartg SA
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[25] Board of Officers in-situ joint investigation of blackened Carts SA 7.62mm A-7 Amn of lots at 10 Inf DOU (101 AP) on 26 Sep to 27 Sep 2022.
[26] Board of Officers in-situ joint investigation of blackened Carts SA 7.62mm A-7 Amn of lots at 21 FAD on 16 to 20 Sep 2022.
[27] Board of Officers in-situ joint investigation of blackened Carts SA 7.62mm A-7 Amn of lots at GC CRPF, Greater Noida (U P) on 30/09/2022 to 01/10/2022.
[28] CQA (Met) Metallurgical Investigation Report of Defect with Amn AMK-50 G Cartg SA 7.62 mm Ball A-7 MK-II Amn dt 10 Aug 2021.
[29] References to Accelerated Tarnish resistance tests – Humidity Chamber test & Sodium Sulfide Test.
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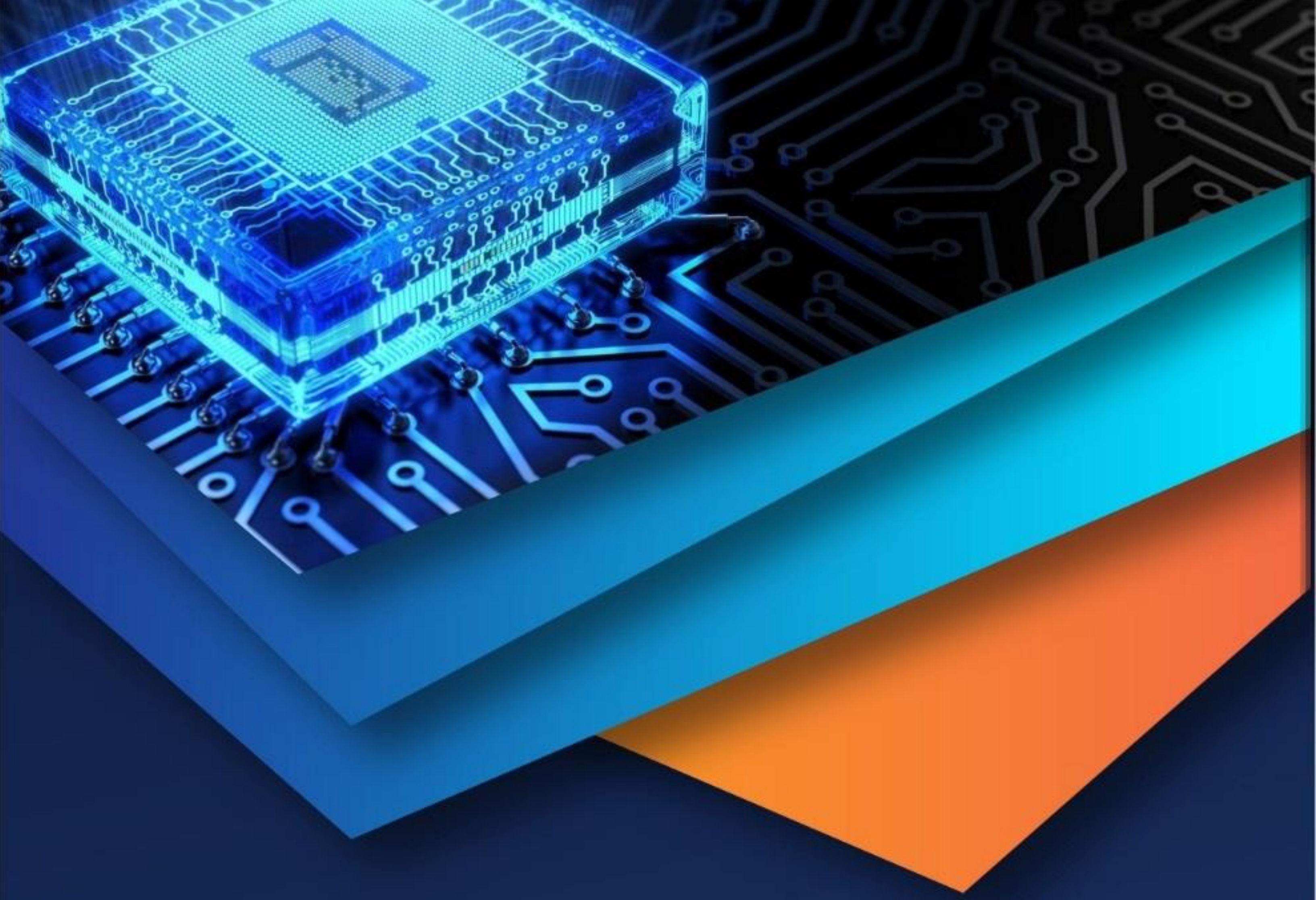

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