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Hard Chrome Plating Inside Of Barrel Bore Of Small Arms Weapons By Using Forward – Reverse Current Technique.

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MINISTRY OF DEFENCE (MoD)

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The present invention relates to advanced Hard Chrome Plating Process inside Barrel bore of Small Arms Weapon by using forward – reverse current. In existing technologies hard chrome plating operation is carried out by using following process sequence:

S.NO.	OPERATION	REMARK IF ANY
01	S/R Before Electro polishing	
02	Electro polishing	Current & time will vary as per components surface area
03	Hot Water Rinsing	
04	Cold Water Rinsing	
05	Passivation	
06	Cleaning With Hot Water & Pull Through	
07	Bore Inspection	No any wire mark
08	Cleaning With Solvent & Pull Throw	
09	Ultra Sonic Cleaning	Time will vary as per components surface area
10	Component Inspection	component should be clean
11	Batch Formation	08 components for each batch with same gauge
12	Anodic Cleaning	Current & time will vary as per components surface area
13	Neutralization	
14	Etching	Current & time will vary as per components surface area
15	Chrome Plating	Current & time will vary as per components surface area
16	Water Rinsing	
17	S/R (Dehydrogenation)	
18	Quality Control Inspection	

Following defects is always occurred in existing technology:

i. Coating peeled off
ii. Coating chip off
iii. Insufficient coating thickness
iv. Absence of coating
v. Uneven coating thickness
vi. Rough coating deposition
vii. Dual color coating
viii. Scratches in coating
ix. Dent

x. Pitting

A lot of trials at different parameters have been conducted to remove aforesaid defects. Finally it is found that when current is given in forward-reverse direction in following sequence, these defects don't occur after processing and proof firing. Process sequence is given below:

S.NO	OPERATION	REMARK IF ANY
01	S/R Before Electro polishing	Bore Inspection : Found O.K.
02	Electro polishing	Not Done
03	Hot Water Rinsing	Not Done
04	Cold Water Rinsing	Not Done
05	Passivation	Not Done
06	Cleaning with Hot Water & Pull Through	Not Done
07	Bore Inspection	Not Done
08	Cleaning With solvent & Pull Throw	Bore Inspection : Found OK
09	Ultra Sonic Cleaning	
10	Component Inspection	Bore Inspection : Found OK
11	Batch Formation	7.70 Gauge enters up to 10mm from Breech End. 7.70 Gauge enter up to 10mm from Muzzle end.
12	Anodic Cleaning	All Parameters are maintained
13	Neutralization	All Parameters are maintained
14	Etching	All Parameters are maintained
15	Chrome Plating	All Parameters are maintained. Forward Current Reverse Current
16	Water Rinsing	All Parameters are maintained
17	S/R (Dehydrogenation)	All Parameters are maintained
18	Quality Control Inspection	Found O.K. I/Note No- 159/S2/EP/21;Dtd: 29/01/22 Wt. No. – 132/0, Operation No: 1430:Proof Chamber 1450: Stamp Proof Mark
19	Burnishing, Chamber Polish, Bore View, Gauging	Found O.K.(01/02/22)
20	Q.C. Submission	All Barrels are passed I/Note No- 164/F/EP/21; Dtd: 02/02/22 Wt. No. – 132/0

a. 06 numbers of MAG Barrels had been chrome plated by using Reversal Unit with Conventional Chrome Bath. All Barrels were finally passed by QC. Three numbers of Gun was made by using these six Barrels. These guns were passed in assembly, Proof Firing and Final Stage Inspection.

b. In this process, Electro polish operation was omitted. As per existing process Barrels to be chrome plated, should be electro polished prior to plating for maintaining conversant. Since Electro Chemical solution is highly viscous so that high temperature (85^0C) is required & after Electro Polish operation following operation is also required to obtain some properties as given below:

S. No.	PROCESS	Description
01	Electro Polish	Electro polishing takes place as a result of the electro chemical removal of a surface layer & the principles of electro polishing are similar to those for electroplating. The major difference concerns the polarity of the work piece being treated. This process is used for making convergent of barrel bore.
02	Hot Water Rinse	Since chemical (highly acidic) used in electro polish is very viscous, so a thick layer is formed inside the bore during operation. To remove such layer, it is washed by hot water.
03	Cold Water Rinse	It is used for cleaning.
04	Passivation	To protect the surface from corrosion, this operation is used.
05	Cleaning by brush & Pull Through	To remove traces of adhered Electro polish chemicals on the inner surface of Barrel.
06	Organic solvent degreasing	Ultra sonic cleaner is used, in which cleaning solvent is used.

i. Since there is no need to Electro Polish Operation, so all operations as mentioned in aforesaid tables are not required.

ii. (a) Saving of electrical energy (to maintained process temperature of Electro Polish & Hot water Bath.
(b) Saving of water (no need of cold water, hot water & passivation Bath).
(c) Saving of Sodium di-chromate ($Na_2Cr_2O_7$) chemical, which is used for passivation ($Na_2Cr_2O_7$ is a hazardous chemical).
(d) Saving of solvent which is used as a cleaning agent after Electro polish operation.
(e) Reduced load on E.T.P.
(f) Saving of SMH, Cycle time is reduced, Shinning is better.

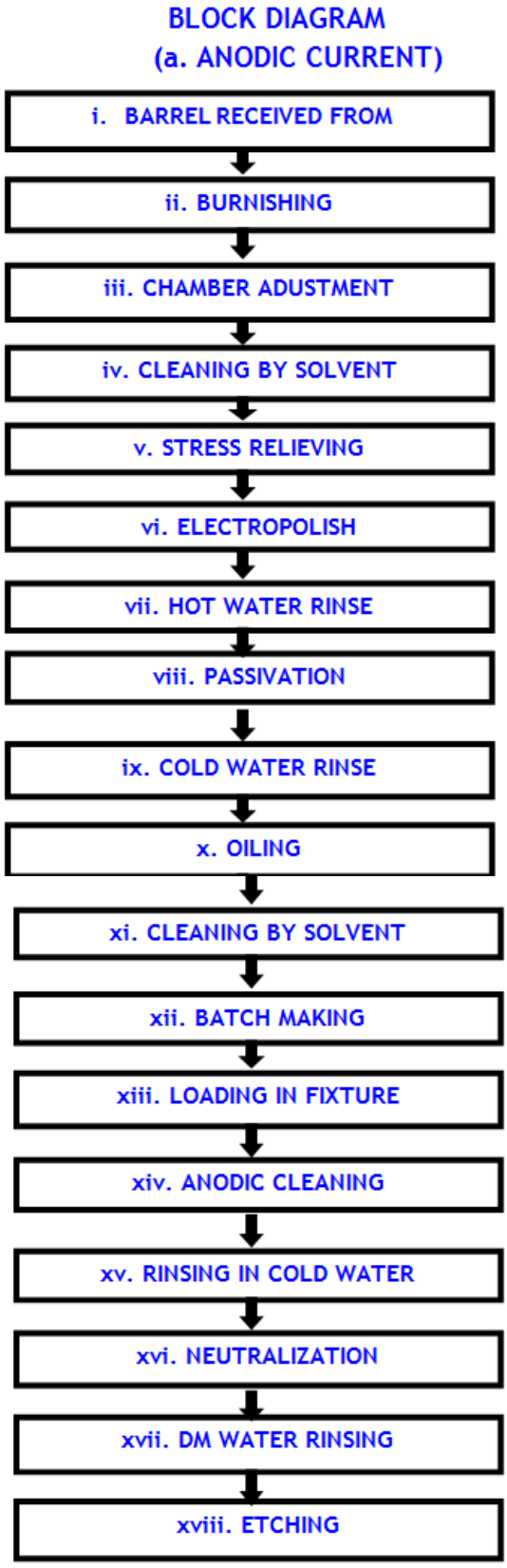
iii. In this process twenty minutes time is given for forward current (forward current is responsible for plating) & then after mode is automatically changed in reverse manner for ten second. After plating reverse current cleans the surface & it is tendency to escape out the trapped hydrogen on the surface, so problem of Hydrogen embrittlement will reduced. Hydrogen Embrittlement is a main cause of chip off inside the Barrel.

BENEFITS OF THE NEW PROCESS:
A. The following operations are obviated after implementation of hard chrome Plating inside the barrel bore of Small Arms Weapons by using forward reverse current technique:

01	Electro polishing
02	Hot Water Rinsing
03	Cold Water Rinsing
04	Passivation
05	Cleaning with Hot Water & Pull Through
06	Bore Inspection

B. Zero Chip off, while in existing process chip off percentage is 15-20%.
C. Reduce the Cycle time (50% reduction).
D. Minimum Load on Effluent Treatment Plant.
E. No customer complaint.
F. Shining/lusture is better than existing process.
G. No rework is required.
H. Fulfill all quality all aspect.
I. No any issue of Hydrogen embrittlement.
J. Applicable to all type of Small Arms Weapons.

EXISTING PROCESS FLOW DIAGRAM:



Steps of Process Flow Diagram

i. BARRELS RECEIVED FROM CWD : There is a section in factory named as CWD(Components work depository Section), which collects different components from different sections & distributes such components in respective sections where next operation to be carried out.

ii. BURNISHING: For cleaning inside the barrels there are burnishing machine. It works on reciprocating motion principle. Emery paper of grit size-80 is used for this purpose.

iii. CHAMBER ADJUSTMENT: Prior to chrome plating inside the barrels, chamber gauges are maintained.

iv. **CLEANING BY TCE:** To remove oil, grease etc prior to plating, components are cleaned by degreasing solvent.

v. **STRESS RELEIVING:** Stress developed by machining operation is released by baking the components at the temperature 200^0C for two hours.

vi. ELECTROPOLISH: Electro polishing takes place as a result of the electro chemical removal of a surface layer & the principles of electro polishing are similar to those for electroplating. The major difference concerns the polarity of the work piece being treated. When electro polishing , the work piece is positively charged, which is achieved by electrically connecting the item being processed to a source of direct current whilst immersed in a chemical solution(Mainly ortho phosphoric acid). This solution, usually acid based, is referred to as an electrolyte & its composition will depend on the metal being treated. The electro chemical circuit is completed by metal cathodes (negative), which are also immersed in the electrolyte solution.

A rectifier which converts alternating current into direct current is the usual means of providing the anodic & cathodic current. Metal is dissolved from the anodic part. Almost immediately large quantities of oxygen are liberated at the surface of the part, forming a dense gaseous layer. Because of the tendency of electrical current to flow from points & projections, these areas are dissolved preferentially. Resulting in a smoothing of the surface. The viscous boundary layer that forms as a result of the gaseous contributes to the preferential dissolution of peaks & the projections. The process is optimized by control of the solution chemistry, temperature, current density & time. Electro polishing solutions are highly acidic & corrosive, requiring the use of corrosion resistant equipment & close attention to worker safety.

vii. HOT WATER RINSE: This process is carried out after electro polishing operation. In electro polishing operation, solution used is very viscous & it makes a thick film layer on the surface of bore. Since this chemical should be removed for next operation. Components is dipped in hot water tank so that solution adhered on the surface can be removed.

viii. COLD WATER RINSE: the purpose of this operation is only for cleaning. This is process requirement for next operation.

ix. PASSIVATION: After electro polish, surface is free from any oxide layer. It is chance to form corrosion layer when components will put in any environment. To protect the surface from corrosion, components are dipped in sodium dichromate solution (2% w/v & Temp. – 55^0C). This solution gives nascent oxygen & since nascent oxygen having tendency of high reactivity so it makes a uniform layer of oxide inside the bore. This is why no corrosion will occur in any environment.

x. OILING: To protect the components from environmental corrosion.

xi. CLEANING BY SOLVENT: To remove oil, grease etc prior to plating, components are cleaned by degreasing solvent.

xii. BATCH MAKING: To maintain coating thickness, a batch of eight barrels are made having same bore size.

xiii. LOADING IN FIXTURE: Components are loaded in fixture for plating operation.

xiv. ANODIC CLEANING: Alkaline cleaners remove organic type soils and have less effect on inorganic soils such as oxides, scale and rust, though many of these may also be removed if they are embedded in the organic soils because they are lifted out with them. Alkaline cleaners work through the processes of saponification, emulsification, solubilization, and preferential wetting. Alkaline cleaners should be water-soluble and their solutions should wet the surface being cleaned, and preferentially wet and penetrate the soil to be removed. They should be temporarily able to emulsify and suspend solid particles in solution without re-depositing them on the metal surface; and they should be able to solubilize or bring into solution those soils capable of dissolving in a reasonable length of time. They should be able to soften water, rinse freely, not attack or tarnish the metal surface being cleaned, have a high buffering capacity, i.e., tolerate drag-in of acid substances introduced with the metal without change of pH; and they should not form excessive foam during cleaning or rinsing. In alkaline soak cleaning, the parts are immersed in tanks of hot alkaline cleaning solution. Concentration and temperature of the cleaner should be as high as possible considering the nature of the work, in order to minimize the time for satisfactory cleaning.

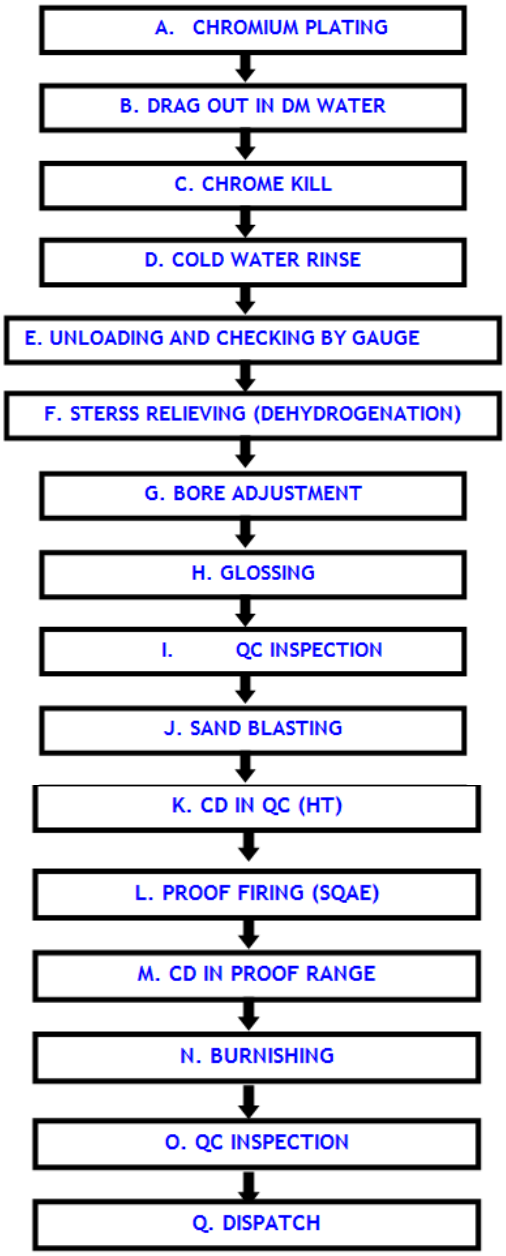
xv. RINSING IN COLD WATER: water rinse is used for cleaning of components.

xvi. NEUTRALIZATION: **Since** Alkaline solution has tendency to convert hexavalent chrome into trivalent chrome so before reverse etching, components are dipped in sulfuric acid (1% v/v & temp: 60^0C) so that traces of alkaline solution could be neutralized.

xvii. D.M. WATER RINSING: To remove last traces of impurities.

xviii. **ETCHING:** Reverse etch is used for the final removal of oxides before chrome plating. The final operations before chrome plating is usually a reverse etch in either a chromium plating solution or a solution of sulfuric acid. This operation removes the last traces of oxides, left on the surface after the cleaning operation; activates the surface of the metal (remember that the initial layer of chrome plate is sometimes very difficult to deposit, and, most importantly, contributes to good adhesion of the chrome plate.) Chromic acid reverse etches are operated at the temperature and concentration of the plating bath. There is danger on some parts of producing a rough deposit if the etch is prolonged much beyond the desired time, which is dependent upon the base metal alloy being plated.

BLOCK DIAGRAM:
(b. CATHODIC CURRENT)



A. CHROME PLATING: Chromium is the hardest of the most commonly deposited metals. Hard chrome is used as a wear resistant coating not only on steel but also on a wide variety of other metals.

CHROME PLATING	CURRENT – 35 AMP/dm^2(Each MAG Barrel) TIME -- 2.20 HOURS(7.70 RUN) TEMP. (^OC) -- 55 SP. GRAVITY (^OBe) – 21 - 22	
Bath Composition	CrO_3	225-275g/l
	SO_4^{--}	2.25 – 275g/l
	Iron Oxide	0-20 g/l
	Cr_2O_3	0-18 g/l
	Total Oxide	0-38 g/l

B. DRAG OUT IN D.M. WATER: To remove adhered chrome solution on the surface of barrels.

C. CHROME KILL: Chrome-Kill (Sodium meta bi sulphide $Na_2S_2O_5$) can be used in the final rinse tank to remove the last traces of the chrome bath, which can later bleed out and stain the parts. Time of contact between the work and the rinse must be sufficient to remove all chemical films; for immersion rinses with air agitation this is usually around 30 - 60 seconds. Another advantage of using Chrome-Kill as the final rinse is that it operates hot and therefore the parts will air dry quickly without requiring a separate drying operation.

D. COLD WATER RINSE: For cleaning the components.

E. UNLOADING & CHECKING BY GAUGES: To ensure that plating thickness is achieved as per required.

F. STRESS RELEIVING(DEHYDROGENATION): A proven method of removal of hydrogen is baking after plating. Thermal treatment of metals for specified times (16 to 18 hrs.) & temperature (200^0C) is driven the hydrogen out from the metal surface & relieve stresses.

G. **BORE ADJUSTMENT:** Bore is adjusted as per process layout.

H. **GLOSSING:** To make shining in the chamber of the Barrels, Glossing is done from breach end side of the Barrel.

I. **Q.**C.INSPECTION: Q.C. Examiner checks the Barrel's quality as per drawing & layout.

J. SAND BLASTING: Before crack detection test, barrels are shined by sand blasting operation.

K. CRACK DETECTION TEST: To ensure that there are no any cracks on the outer surface of barrel before high pressure proof, crack detection test is required.

L. PROOF FIRING: To check ability of barrels to wear pressure load, one high pressure proof firing is done in each barrel.

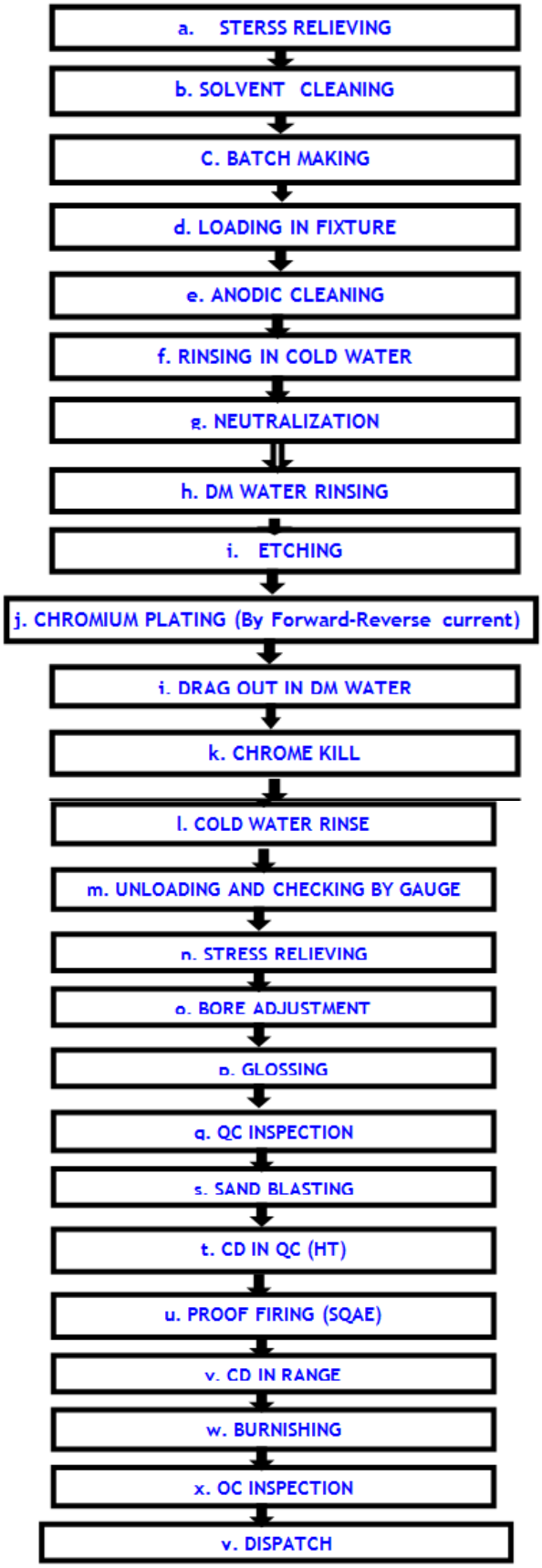
M. C.D. IN PROOF RANGE: To ensure that there are no any cracks on the outer surface of barrel after high pressure proof, crack detection test is required.

N. BURNISHING: To clean the Barrel bore.

O. Q.C. INSPECTION: Q.C. Examiner checks the Barrel's quality as per drawing & layout.

P. **DISPATCH: Barrels are collected by CWD(Component Work Depository Section) & it is sent to next section by CWD.**

INVENTED PROCESS FLOW DIAGRAM:



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j. CHROME PLATING(BY FORWARD-REVERSE CURRENT): Chromium is the hardest of the most commonly deposited metals. Hard chrome is used as a wear resistant coating not only on steel but also on a wide variety of other metals.

<table>
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TIME - 2.20 HOURS(7.70 RUN)
TEMP. (^{O}C) - 55
SP. GRAVITY (^{O}Be) – 21 - 22</td></tr>
<tr><td rowspan="5">Bath Composition</td><td>CrO_3</td><td>225-275g/l</td></tr>
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<tr><td>Total Oxide</td><td>0-38 g/l</td></tr>
<tr><td>Forward – Reverse current(According to Chargeman Log Book)</td><td colspan="2">Tank No. – B-13(II)
Forward Current – 20 minutes
Reverse current - 10 second
Dead Time - 05mS</td></tr>
<tr><td>Barrel No.</td><td colspan="2">BA-9422,9438,9454,9450,8819,9426</td></tr>
<tr><td>I/Note No.</td><td colspan="2">(i)Found O.K.
I/Note No- 159/S2/EP/21;Dtd: 29/01/22
Wt. No. – 132/0, Operation No:
1430:Proof Chamber
1450: Stamp Proof Mark
(ii)All Barrels are passed
I/Note No- 164/F/EP/21; Dtd: 02/02/22
Wt. No. – 132/0</td></tr>
<tr><td>Gun Number</td><td colspan="2">Gun No. Date of Passing</td></tr>
</table>

	(i)4196(17783643) 04/03/22 (ii)4197(17783650) 07/03/22 (iii)4198(17783814) 04/04/22
I/Note No.	

k. DRAG OUT IN D.M. WATER: To remove adhered chrome solution on the surface of barrels.

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p. BORE ADJUSTMENT: Bore is adjusted as per process layout.

q. GLOSSING: To make shining in the chamber of the Barrels, Glossing is done from breach end side of the Barrel.

r. Q.C.INSPECTION: Q.C. Examiner checks the Barrel's quality as per drawing & layout.

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t. CRACK DETECTION TEST: To ensure that there are no any cracks on the outer surface of barrel before high pressure proof, crack detection test is required.

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x. Q.C. INSPECTION: Q.C. Examiner checks the Barrel's quality as per drawing & layout.

y. DISPATCH: Barrels are collected by CWD(Component Work Depository Section) & it is sent to next section by CWD.

Conclusion:

03nos of guns (06 nos of barrels) have been passed by the invented process. Final inspection Note has been issued to Indian Army depot which is proof evidence of invented process to comply all the acceptance criteria of Director General Quality Assurance (DGQA) inspection which is started from in house Quality Control inspection followed by DGQA Estt i.e. Senior Quality Assurance Estt(SA), Kanpur. the inspection procedure followed as High Pressure Proof of Barrels, Pre Inspection, Proof Range Firing & Final Acceptance Inspection before issue to inspection Note. All the three guns meeting all the standards and issued to Indian Army Depot (COD) Jabalpur.