OTTAWA   April 1st, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1618.

Quality Control Procedures for Ammunition Manufacture.

Bureau of Mines
Division of Metallic
    Minerals,
    —
  Ore Dressing
and Metallurgical
  Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Origin of Request:

The following is a copy of the original request

to conduct this investigation:

"DEPARTMENT OF MUNITIONS AND SUPPLY
OTTAWA,   Canada   (A & SAA Br.   )
                          (File No. 27-19)
                 March 7, 1944.

Dept. of Mines and Resources,
Division of Metallic Minerals,
552 Booth Street,
Ottawa, Ontario.
               Attention: Mr. H.H. Fairfield.

Dear Sirs:

        The Management of York Arsenals Limited,
832 Old Weston Road, Toronto, have requested us to obtain
your assistance and advice in their setting up of Process
Quality Control on Automatic Screw Machine operations
which consist principally of their production of 20-mm.
Shell and other components for us.

        We are entirely in accord with their
request and would appreciate such assistance as you may
be able to give them, including such periodic visits as
it may be necessary for you or your representative to
make to their plant.

        Toward this end, the writer will be at
their plant on Friday, March 10, and it is suggested
that you might wish to have a representative there at
that time.

               Yours very truly,

               (Sgd.)   L. C. Ruby,
               for Director General
LCR:ss.   Arsenals & S.A.A. Branch."

Introduction to Problem:

        The problem at York Arsenals Limited is to control the amount of defective pieces produced.

        Quality Control methods have been devised and are quite widely used to handle this situation. Although the actual procedure may differ from plant to plant, the main principles are the same wherever quality control is applied. The present report sets forth a quality control program which is designed to aid the management of York Arsenals Limited in reducing the per cent defective in their product.

        When per cent defective approaches zero, another plan is employed; it is known as "dimensional" control.

        The main idea involved in quality control is "The more that is known about a situation the better chance there is that something can be done to improve it". Quality control methods provide information only; it is then up to Management to make use of the information.

Suggested Inspection Plan:

        The plan for York Arsenals Limited is divided into four operations. The purpose and method of each operation are indicated in the following sections of this report:

1. - MACHINE CHECK.

        It is considered desirable to check a sample (from every screw machine spindle) at frequent intervals. The time interval will depend upon how long it takes a machine to get "off". It may be every 10 minutes in some cases, or only every 60 minutes when things are running smoothly.

        By frequent machine checks trouble can be discovered at an early stage. When trouble is discovered, action should be started immediately. Plant management will arrange for this. A tentative suggestion is that a red light be mounted

(Suggested Inspection Plan, cont'd) -

above the machine in a conspicuous position. When machine check inspection shows something wrong the red light should be turned on. Some other spectacular method may be devised. The main idea is that the proper people are made aware that corrective action is necessary.

It is also recommended that a record be kept of the corrective steps made.

Figure 1 (on Page 4) shows the information that should be recorded for each shift. The machine check record provides basic date on machining operations which can be studied by the production engineers. Performance of machines, operators, and set-up men can be compared. The frequency of various adjustments can be recorded.

2. - SHIFT RECORD.

At the end of a shift the quality of the work can be rated from the number inspected and the number found to be defective. The maximum outgoing per cent defective can be calculated as follows:

EXAMPLE:

Number inspected, 196 = n.
Number defective, 18 = x.

Per cent defective $= \frac{18}{196} \times 100 = 9.18$ per cent.

Maximum outgoing per cent defective

$$= \left(\frac{x}{n} + 1.5 \sqrt{ \frac{x}{n} \cdot \frac{(n-x)}{n} \cdot \frac{1}{n} } \right) 100$$

$$= \left(\frac{18}{196} + 1.5 \sqrt{ \frac{18}{196} \cdot \frac{168}{196} \cdot \frac{1}{196} } \right) 100$$

$$= \left(0.9184 + \frac{1.5}{196} \sqrt{15.4} \right) 100$$

$$= \left(0.918 + \frac{5.88}{196} \right) 100$$

$$= (0.918 + .03) 100$$

$$= 12.18 \text{ per cent}$$

FIG. 1

MACHINE CHECK RECORD

| PART | MACHINE No. | | SHIFT | | DATE | MARCH 1. |

DIMENSION		8:15	8:30	8:45	3:00		
TOTAL LENGTH	HIGH / LOW					MACHINE OPER.........	
OUTSIDE DIAM.	HIGH / LOW	1				SET UP MAN........	
INSIDE DIAM.	HIGH / LOW				2	PROD. FOREMAN......,	
HOLE DEPTH	HIGH / LOW					INSPECTOR R.P. Collins	
THREADS		1					
FINISH			1			No. INSPECTED ..196..	
						No. DEFECTIVE ..18...	
TOTAL DEFECTIVES		2	1	0	2	TOTAL % DEFECTIVE. 9.2	
No. INSPECTED		6	6	6	6		
ACTION TAKEN		ADJUSTED CUT OFF TOOL J.C.B.	ADJUSTED FORM TOOL R.H.W.				

(Suggested Inspection Plan, cont'd) -

Therefore, having obtained 18 defects in 196 pieces the product is rated as under 12.18 per cent defective. There are several ways to calculate the quality "ceiling". The simple method given above is easy to carry out. A chart from the "Engineers' Manual of Statistical Methods" is included (Figure 7, on Page 14), from which the maximum per cent defective can be derived. Other methods are equally good.

The shift record gives a picture of day-to-day conditions. Also, the shift record can be used to pass sentence upon the work of a shift. If, for example, under 2 per cent defective was considered as a satisfactory product, then each shift could be classed as either "O.K." or "Reject". The rejected shift work would be sent for 100 per cent inspection.

Necessary evidence to be sure that a lot of parts are below 2 per cent defective* is:

```
(1)     Zero defects in    70 pieces,
(2)  1 or less defects in 125    "    ,
(3)  2   "     "        "    "  200    "    ,
(4)  3   "     "        "    "  265    "    ,
(5)  4   "     "        "    "  335    "    ,
(6)  5   "     "        "    "  400    "    ,
(7)  6   "     "        "    "  460    "    ,
            etc., etc.
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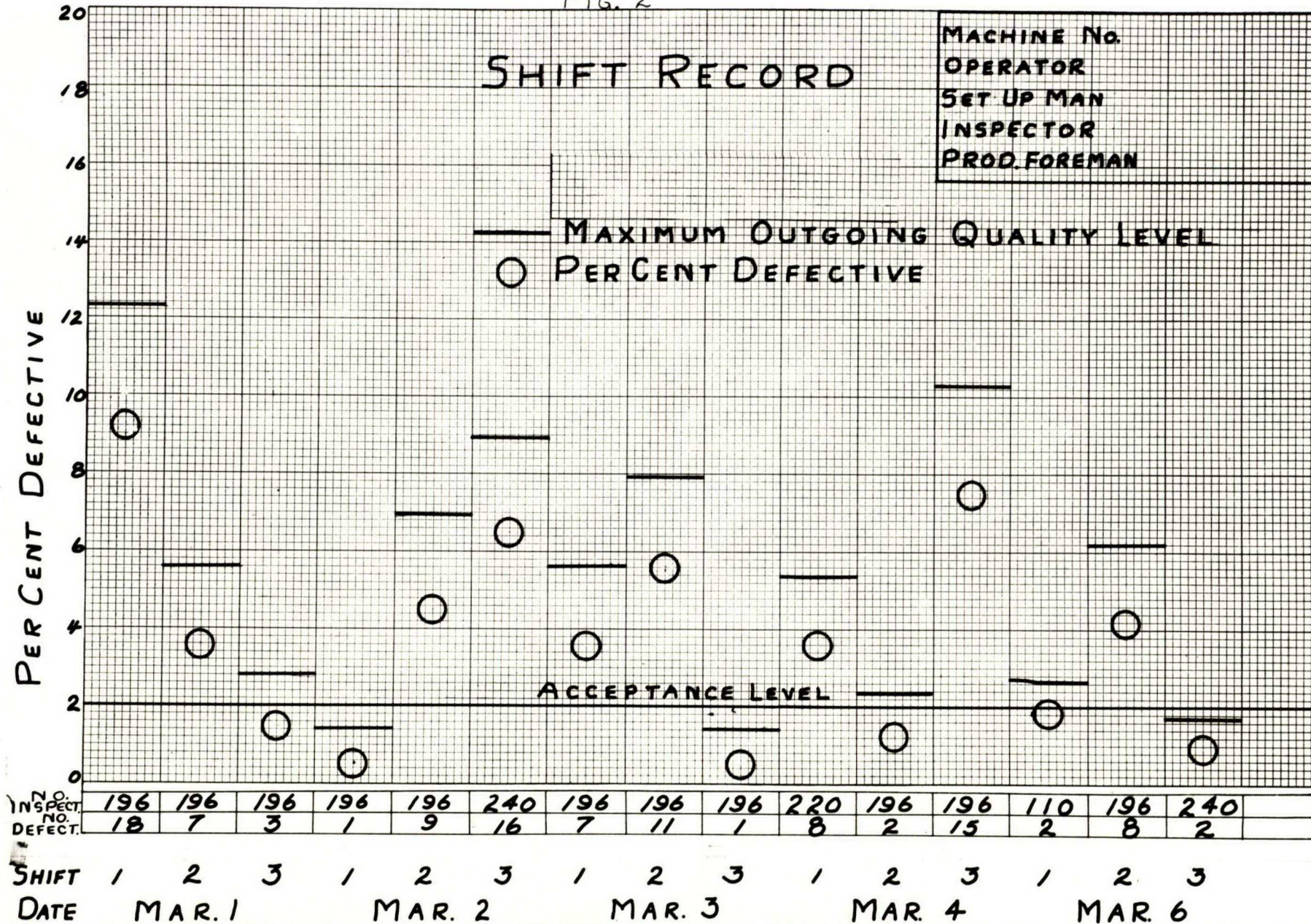
(Figure 2, Shift Record,)
(comprises Page 6.   )

3. - 100 PER-CENT INSPECTION.

The operation of 100 per cent manual inspection has been studied by many investigators. The general conclusion is that an experienced inspector will pick out about 90 per cent of the defective articles presented for inspection. The per cent of defects detected will vary with individuals. Also, an individual inspector will vary in efficiency from time to

---

* From "An Engineers' Manual of Statistical Methods".

FIG. 2

SHIFT RECORD

MACHINE No.
OPERATOR
SET UP MAN
INSPECTOR
PROD. FOREMAN

—— MAXIMUM OUTGOING QUALITY LEVEL
○ PER CENT DEFECTIVE

ACCEPTANCE LEVEL ——

PER CENT DEFECTIVE

20
18
16
14
12
10
8
6
4
2
0

NO. INSPECT	196	196	196	196	196	240	196	196	196	220	196	196	110	196	240	
NO. DEFECT.	18	7	3	1	9	16	7	11	1	8	2	15	2	8	2	
SHIFT	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
DATE	MAR. 1			MAR. 2			MAR. 3			MAR. 4			MAR. 6			

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(Suggested Inspection Plan, cont'd) -

time. The "human error" in this type of work cannot be entirely eliminated.

It is recommended that the work of each inspector or inspection bench be tagged, so that if defects are found in a subsequent examination the responsibility can be traced.

4. - DOUBLE SAMPLING.

Since 100 per cent inspection is subject to human error, it is necessary to inspect again in order to see how well this inspection has been carried out. The final inspection is also used to rate the product.

United States Ordnance have worked out all of the details of this method. The following are examples of their procedure:

Sample size depends upon lot size. Figure 3 (on Page 8) shows the sizes of samples required and the number of defects permitted for various quality levels.

Figure 4 (Page 9) shows a record of double sampling inspection. The instructions to inspectors are given in detail in Figure 5 (on Page 10).

A flow chart of final inspection procedure is shown on Figure 6 (Page 11). Note that O.K. shifts by-pass 100 per cent inspection. Trays from each inspector are tagged. The tagged tray moves to the double-sampling station, where it is sampled. If defects are found the tray is shunted back to a master inspector who re-inspects 100 per cent. In this way the producer has a check on the work of each inspector.

Trays clear of defects are piled up until a lot has been accumulated. This lot is then sentenced by the double sampling station. O.K.'d lots move on to the next operation or are presented to the customer. Rejected lots are inspected again.

FIG. 3

STANDARD SAMPLING INSPECTION TABLES

TABLE I.—NORMAL LOT-BY-LOT ACCEPTANCE INSPECTION

Sub-Lot Size		500–799		800–1,299		1,300–3,199		3,200–7,999		8,000–21,999		22,000–109,999		110,000 and Over		Maximum AOQL (Percent Defective)
First Sample Size		50		75		100		150		200		300		500		
Second Sample Size		100		150		200		300		400		600		1,000		
Acceptable Quality Level (Percent Defective)		Acceptance Numbers		Acceptance Numbers		Acceptance Numbers		Acceptance Numbers		Acceptance Numbers		Acceptance Numbers		Acceptance Numbers		
Major	Minor	c_1	c_2	c_1	c_2	c_1	c_2	c_1	c_2	c_1	c_2	c_1	c_2	c_1	c_2	
.010–.020		*	*	*	*	*	*	*	*	*	*	*	*	0	1	.08
.021–.030	.010–.020	*	*	*	*	*	*	*	*	*	*	0	1	0	2	.15
.031–.060	.021–.030	*	*	*	*	*	*	*	*	0	1	0	2	1	3	.20
.061–.10	.031–.060	*	*	*	*	*	*	0	1	0	2	1	2	1	4	.30
.11–.15	.061–.10	*	*	*	*	0	1	0	2	0	3	1	3	2	5	.40
.16–.25	.11–.15	*	*	0	1	0	2	1	3	1	4	2	5	3	7	.60
.26–.50	.16–.25	0	2	1	2	1	3	2	4	2	7	3	8	4	13	1.0
.51–1.0	.26–.50	1	3	2	4	2	6	3	9	4	11	5	13	7	23	1.7
1.1–2.0	.51–1.0	2	4	3	5	3	8	5	13	6	16	8	25	14	40	2.7
2.1–3.0	1.1–2.0	3	5	4	8	5	11	7	18	9	24	12	35	†	†	3.7
3.1–4.0	2.1–3.0	3	9	5	11	6	16	9	23	11	32	16	47	†	†	4.2
4.1–5.0	3.1–4.0	4	10	6	14	8	19	11	28	14	37	†	†	†	†	5.3
	4.1–5.0	5	12	7	17	10	23	14	33	18	44	†	†	†	†	6.5

*Table not applicable in this region.   †Use sample size in first columns to left in which acceptance numbers are shown for Acceptable Quality Level involved.

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PROCEDURE:
   1. FOR MAJOR DEFECTS:
         a. Select first sample of size indicated in Table I for sub-lot size involved.
         b. Determine in first sample the number of articles, d_1, which contain major defects.
               (1) If d_1 does not exceed the c_1 indicated for the Acceptable Quality Level, Major, involved: Pass sub-lot for Majors.
               (2) If d_1 exceeds the corresponding c_2: Reject sub-lot.
               (3) If d_1 exceeds c_1, but does not exceed c_2:
                     (a) Select second sample of size indicated in Table I.
                     (b) Determine in second sample the number of articles, d_2, which contain major defects.
                           1. If d_1+d_2 does not exceed c_2: Pass sub-lot.
                           2. If d_1+d_2 exceeds c_2: Reject sub-lot.
   2. FOR MINOR DEFECTS:
         Carry out above procedure with "Minor" substituted everywhere for "Major," using same sample wherever feasible.

   3. DISPOSITION OF SUB-LOT:
         a. If passed for both major and minor defects by above procedure: Accept as conforming.
         b. If rejected for either major or minor defects by above procedure: Return to contractor.

NOTES:
      Reject all defective articles observed in any of the above inspections.
      AOQL values in right-hand column are poorest average quality accepted if all rejected lots are inspected 100 percent and accepted after removal of all defective articles.
      Above procedure is satisfactory when process average is equal to or better than Acceptable Quality Level. If process average is poorer than this, acceptance numbers that correspond with the AOQL value which is equal to or next better than the Acceptable Quality Level should be used.

FIG 4.

LOT QUALITY DETERMINATION

Date. MAR 1.   Part No. 900072   Station No. 3. . .

(MAJOR) LIST OF DEFECTS	DIMENSIONS	GAUGE NO.	1ST. SAMPLE SIZE. 10.0 DEFECTS	2ND. SAMPLE SIZE. 200 DEFECTS
DIA. OF BOURRELET	1.567 - .005	6007	O.K.	
DIA. OF TRACER CAVITY	.500 -+.01	6009	O.K.	
DIA. OF BAND	1.630 - .004	6010	O.K.	
DIA. REAR OF BAND	1.547 - .005	6011	O.K.	
WEIGHT	1.94 -+.04	6014	O.K.	
ECC. BETWEEN BODY & BAND	.012	6015	O.K.	
ECC. BETWEEN TRACER CAVITY & BODY	.02	6017	O.K.	
ECC. BETWEEN BASE & BODY	.012	6019	O.K.	
ECC. BETWEEN SHIELD & BODY	.012	6020	O.K.	
POSITION OF BAND FROM BASE	.803 - .01	6024	O.K.	

TOTAL DEFECTIVES __ _ O _ _   TOTALS __ O __

(MINOR) LIST OF DEFECTS	DIMENSIONS	GAUGE NO.	DEFECTS	DEFECTS
DEPTH OF C'SINK	.03 + .03 15°	7002	O.K.	
PROFILE OF BAND		7004	O.K.	
POSITION OF W'SHIELD CRIMP			O.K.	
DEPTH OF TRACER CAVITY	.95 + .02	7007	O.K.	
OVER ALL LENGTH	6.190 MAX.	7008	O.K.	
MISC. REJECTS:			O.K. (none)	

TOTAL DEFECTIVES __ _ O _ _   TOTALS __ O _ _ _

SUB-LOT NO. 290.

SUB-LOT SIZE. 1900 PC'S

DISPOSITION..... accepted.   SIGNATURE OF INSPECTOR . S. Holmes.
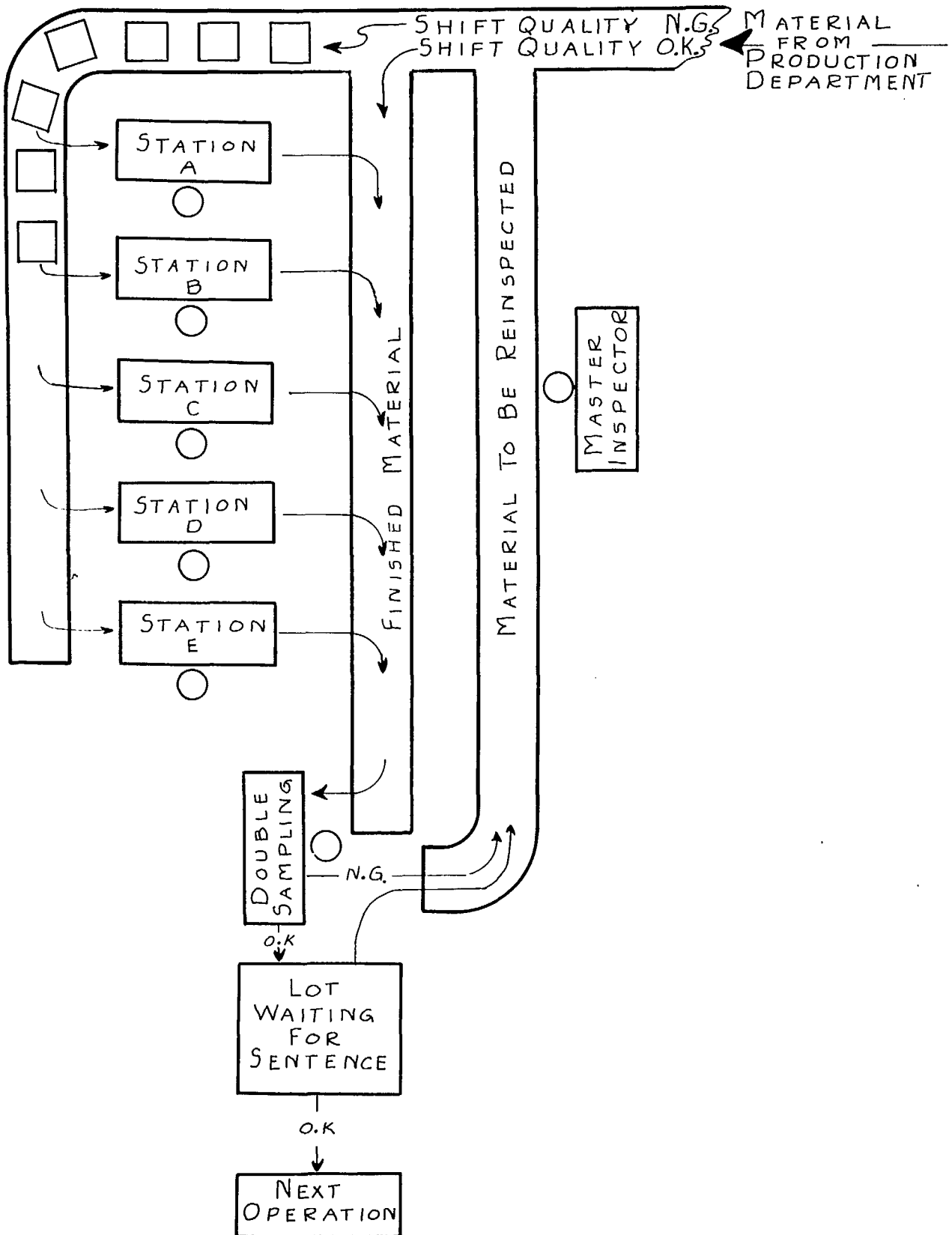
DID YOU HAVE A HELPER? no.

IF SO, WHO?

FIG. 5

PART NO. 900072

DATE MAR1.

	ACCEPTABLE QUALITY LEVELS	
	Major .11 - .15	Minor .16 - .25
SUB-LOT RANGE 1300 - 1399		
FIRST SAMPLE SIZE . 100 . . .		
SECOND SAMPLE SIZE 200 . . .		
TOTAL ALLOWABLE MAJOR DEFECTIVES OF FIRST SAMPLE	0	
TOTAL ALLOWABLE MAJOR DEFECTIVES OF FIRST & SECOND SAMPLES	1	
TOTAL ALLOWABLE MINOR DEFECTIVES OF FIRST SAMPLE		1
TOTAL ALLOWABLE MINOR DEFECTIVES OF FIRST & SECOND SAMPLES		3

FIG. 6

(Page 11)

FLOW OF MATERIAL DURING INSPECTION

MATERIAL NOT INSPECTED

SHIFT QUALITY N.G.

SHIFT QUALITY O.K.

MATERIAL FROM PRODUCTION DEPARTMENT

STATION A

STATION B

STATION C

STATION D

STATION E

FINISHED MATERIAL

MATERIAL TO BE REINSPECTED

MASTER INSPECTOR

DOUBLE SAMPLING

N.G.

O.K

LOT WAITING FOR SENTENCE

O.K

NEXT OPERATION

DISCUSSION:

Four inspection operations required for scientific quality control are:

1. Machine checks.
2. Shift record.
3. 100 per cent inspection.
4. Double sampling.

Operations Nos. 1 and 2 show Management what is going on and provide basic data that can be studied by production men.

Operation No. 4 acts as a check on 100 per cent inspection and gives Management a picture of the quality of the product.

The method proposed would entail more inspection work than is done at present by York Arsenals Limited. However, if this method would help to achieve increased production, reduced costs, or a reduction in scrap, it might prove to be a very profitable investment.

It is recommended that York Arsenals Limited try out the quality control method on one or two machines. After the experimental set-up has been running for a while, it can be compared with average production and the value of quality control to York Arsenals Limited can thus be measured.

The quality control unit can then be gradually expanded to cover as many of the factory operations as required.

When York Arsenals Limited are ready to undertake this project, the Physical Metallurgy Research Laboratories will give any assistance that is needed.

The function of quality control as outlined in this report is to present a picture of what is going on in the process of manufacture. Management will be able to see what is happening and should then be able to take action which will bring the process under closer control.

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HHF:GHB.

APPENDIX.

The chart on the next page shows how to determine the quality of a lot of material taken from a sample. Some examples from this chart are as follows:

Number of pieces inspected	Number of defects found	Maximum probable per cent defective in lot
10	0	19.0
50	2	10.0
100	5	9.0
400	1	1.0
500	50	11.6

The chart will be very useful in rating a shift or small lots of material. For complete description of the use of this and other charts, see "An Engineers' Manual of Statistical Methods" by L. E. Simon, published in 1941 by John Wiley & Sons, Inc., New York.
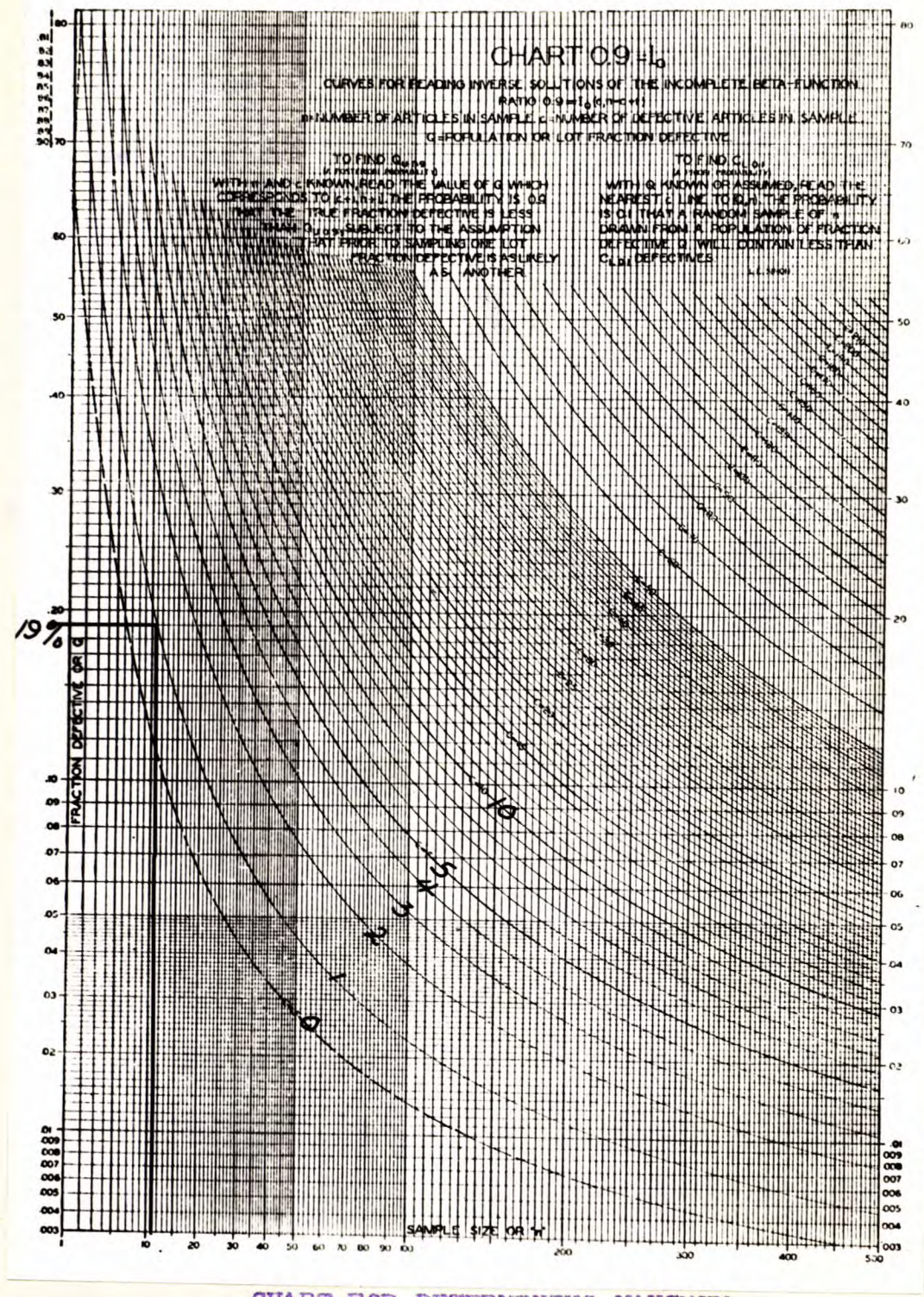
HHF:GHB.

Figure 7.

CHART FOR DETERMINING MAXIMUM
PROBABLE PER CENT DEFECTIVE.

EXAMPLE:

10 pieces examined,
0 defects found.

At intersection of 0 + 1 and 10 + 1 the per cent
defective indicated is 19 per cent. The material sampled is
under 19 per cent defective.

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