DIMENSIONAL ACCURACY OF MAIN MACHINERY

by

A. H. L. TRAPNELL

PART III

PLANNING AND PRODUCTION METHODS

While design may be properly considered a foundation of the dimensional accuracy of main machinery, and inspection must assume responsibility for the verification of such accuracy, it is at the production stage that either the required accuracy will be achieved, or the advantages of a sound design will be nullified. Much attention has been given to planning for large scale production, but it has not been observed that the production of small quantities of engineering manufacture receives similar attention. This is a matter of economics, and while large sums of money can be economically expended in devising ways and means for the production of thousands of radios, little will be available for planning the production of a product which has a small market. Marine machinery may, at first sight, be classified in the latter category, but it is suggested that the economics of main machinery warrants judicious expenditure on planning and production methods. The first cost of main machinery is considerable and is followed by maintenance and operative costs. In the days when a set of machinery could be adjusted, hand fitted, and modified until it gave satisfactory performance, there was no very great requirement for production planning. As assembled units and itemised parts are now required to be interchangeable, it is no longer possible to adjust and modify without loss of interchangeability. An expenditure upon pre-planning and investigation into " ways and means " may, therefore, now be considered economic for the limited production of machinery, when such machinery of high first cost is either to be dimensionally accurate, or unacceptable to specified requirements.

The highly skilled craftsman should not be occupied with the precise manufacture of parts by methods best known to him, but he should be employed in examining the machinery design as a whole and should determine the best method of approach to attain the stated design requirements economically, assuredly, and without resource to special craftsmanship.

A desirable planning arrangement for such work as main machinery construction may be divided into sections, but it must be borne in mind that these are closely inter-related and much liaison is necessary for their successful conduct. They are :—

(i) Methods Planning.
(ii) Time Planning.
(iii) Progress Planning.

Methods Planning

Methods planning must necessarily be undertaken before items of time planning and progress planning can proceed. It consists of examination and breakdown of the design as a whole into comprehensive units and/or assemblies ; each such unit, or assembly, is then further broken down into its constituent sub-assemblies or itemised parts. The breakdown is continued in methodical order until the whole design has been reduced to individual components.

In the production of steam turbines, the initial breakdown is largely automatic and is brought about by the division of contract and sub-contract. Thus one contractor may manufacture the control valves, another the bulkhead valves, a third the turbine unit, a fourth the blading, and so on.

Each contractor should then proceed with the methods planning of his particular part, or parts. Having resolved the part into its constituent details the skilled planning personnel should devise the best known method for producing such details, stipulating the machine upon which the detail is to be made, or the grade of labour to be employed for hand work. For example, it will not suffice to stipulate " milling machine " ; the planning engineer should examine, or know, the aptitude of each milling machine in the works and select the one most suited for the job. It may well be that the machine-loading records, referred to in progress planning, will disclose that the most apt machine will not be available at the time when production is required. The economics involved by waiting until the most appropriate machine could be used, as against extemporising on an available machine with possible requirements of additional tools, longer machining time, or other factors, must be assessed and the appropriate action decided upon.

Having decided which machine is to be used, consideration should be given to cutting tools, jigs and fixtures, materials, and measuring equipment required. Any special handling facilities, space, or preliminary ordering, such as for castings required, should also be considered at this time.

The planning engineer's duties may, or may not, include the design of any tools or equipment which he may specify. This will depend upon the nature of the work, the organisation, and whether tool design facilities exist. It should be his first duty to record in an intelligible manner, the nature of his special requirements for the later attention of the appropriate personnel.

A typical methods layout sheet, indicating the stage reached in methods planning, is shown as Table I on pages 96 and 97.

Time Planning

Time planning enables the relative values of alternative methods of production to be ascertained in advance. It consists of timing each operation of the methods plan, or alternative plans, and serves as a basis for ascertaining costs and providing progressing data. It should not be undertaken by guesswork, nor yet by demonstration, as both are liable to error. The true basis of time planning is calculation. After a particular machine has been specified, its speed and feeds will be known and the machining time, using specified tools, will be easily calculable for removal of a known mass of material in a particular manner. The human element, the time taken for machine loading and unloading, and incidentals cannot be accurately assessed, but more guidance can be obtained, however, from the appropriate time and motion study methods. Given all possible guidance (handling, equipment, etc.) by the methods plan, the rate fixer or time planner can reach a fair assessment of the time to be taken in loading, etc. Any great divergence from the rate specified can be invaluable in disclosing sources of loss of economy, and investigation will enable a true economy to be restored.

The time planning is not necessarily undertaken by different personnel from those employed on methods planning, but where done by the same man, an honest investigation into alternative methods, based upon commensurate rating, must be carried out.

Progress Planning

Progress planning is very important and should not become, as so often happens, progress " chasing." Where a " chaser " is necessary to bring production into line with the planning, it can be safely said that some portion of the planning is at fault. A progressing organisation should be designed to ensure a successful plan for the assured delivery, or manufacture, of the required parts in the required time.

Progress planning consists of scheduling the time-planned details for the final assembly. Periods of machining time for each machine can be ascertained from such a schedule and a loading chart can be compiled giving advance information of the commitments for each machine. A similar schedule will determine the hand work commitments. Details which will be required early in the assembly will become apparent from the above-mentioned schedule. These can be allocated priority on the relevant machine, and where any loading entails undue waiting the methods planner should examine the economic possibilities of using an alternative machine. The longer processes should be loaded early in the machine programme, and the orders for items to be purchased outside the firm should be prepared at the same time to ensure their arrival as required. As an example, it is very desirable that a customer placing an order for, say, turbine blades, should be informed of the definite date when he can expect to receive the blades. From the methods plan it can be ascertained that, perhaps, six operations have to be undertaken involving four machines. The machine loading charts of the progress plan will indicate existing commitments for these specific machines ; the time plan will disclose the additional load, the assembly time (if any), and the handling time. Thus an authoritative date is obtained for completion of the order to its specific requirements. The problem of material supply has been excluded from this example as with the present unstable economic conditions this is an apparently uncontrollable factor which, however, it is hoped, will not exist indefinitely. Even now, the application of good planning to the problem of material supply can help and should do much to remove existing uncertainties. Where such conditions of uncertainty exist over long periods a good planner will prepare a "probability" curve from experiences gained. This is preferred to the conditions of complete ignorance which so often exist to-day.

To ensure the maintenance of a planned programme it is essential that the standard of workmanship is ensured, as a part delivered or completed to time, but unusable, would be no asset. Inspection during manufacture will provide what assurances are possible in this matter and is discussed in Part IV of this paper.

It is not contended that the combination of planning will ensure dimensional accuracy. It is considered that a systematic approach to the work to be undertaken, with a maximum of liaison between planning staff, designers, and inspectors, will enable all reasonable precautions to be taken from which dimensional accuracy should result. One bad time rating, an inefficient methods plan, or a progressing error, will dislocate a whole planned programme. The result becomes chaos and the original good intentions become lost in an endeavour to regain the planned position. Dimensional accuracy may be the feature abandoned in such an eventuality. Could a more sound case be argued, for the utilisation of the skilled craftsman in planning and not in actual production ?

The details of a comprehensive planning organisation have been omitted from this paper as they are not primarily involved in the attainment of dimensional accuracy ; there are many forms, and they vary according to the nature of the work and the organisation. It is a requirement that some such system be adopted to supersede that condition whereby the shop foreman is left to decide the machine to be used, the order of machining, and the method and tools to be used. To consider the shop foreman as the general factotum who controls staff as an administrator, who directs processes as a technician, and

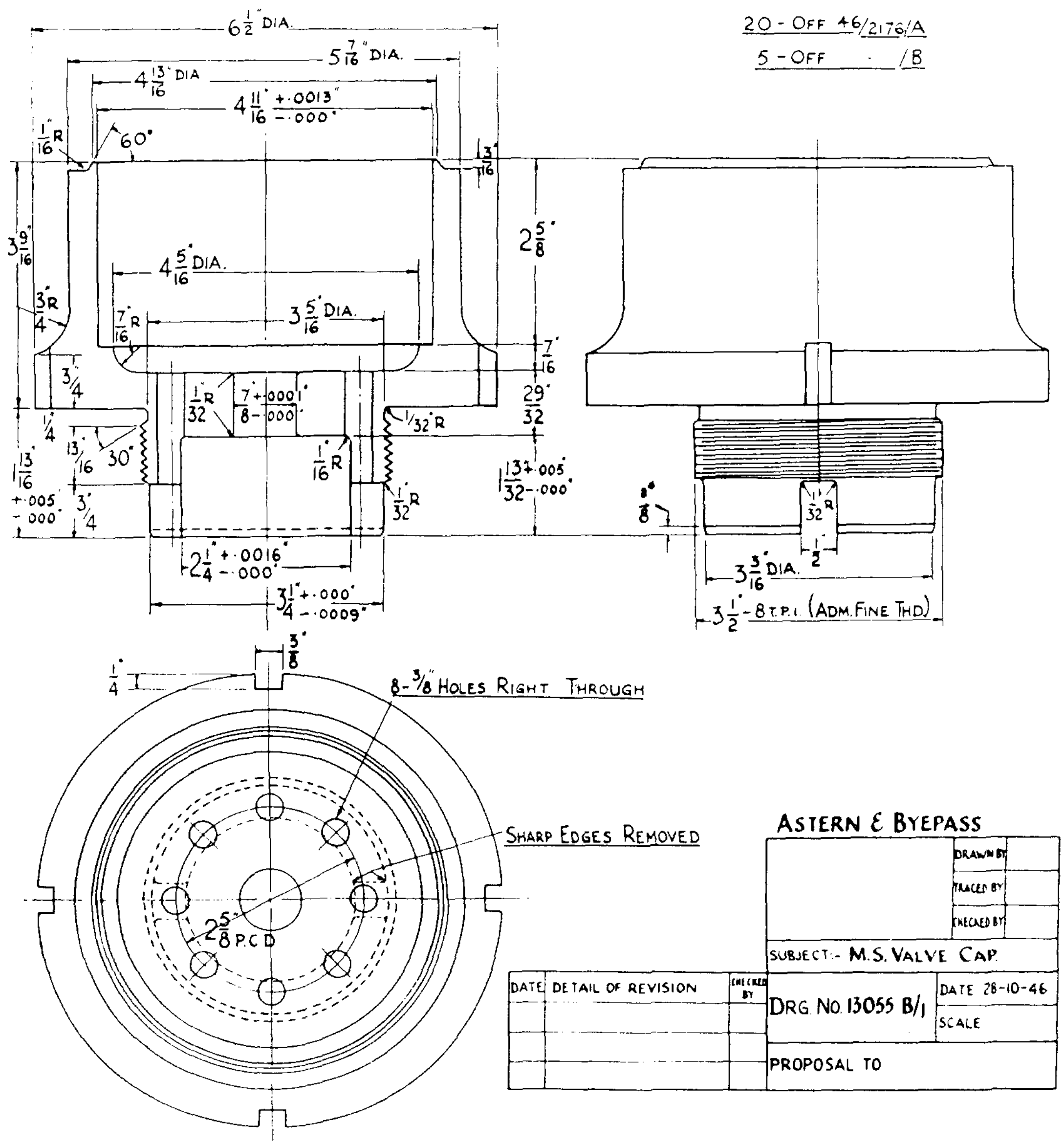


FIG. 1

assumes responsibility for the accuracy of the product as an inspector, is to take an extremely short view of the economics of engineering construction. The first cost, recorded as the foreman's salary, will appear to be low. The incidentals arising have a tendency to become absorbed in other aspects of cost and a belief often exists that the system is economically sound, but this will not bear close, honest, investigation. For the greater initial expenditure on an adequate, but not elaborate planning, an improved true economy will be obtained.

Figures 1 and 2 and Tables I and II serve as an example of process planning. Both Tables and Figure 2 are founded on Figure 1. It is worthy of note that in compiling these planning sheets three features of the original approved drawing of a component now awaiting for a Daring Class destroyer had to be referred to the designer for clarification of intention. The planning sheet has thus removed three possible sources of error. Figure 1 has been modified to give the clear interpretation.

TABLE I

PLANNING SHEET
Type : DARING Class Destroyers
Description : Valve Cap

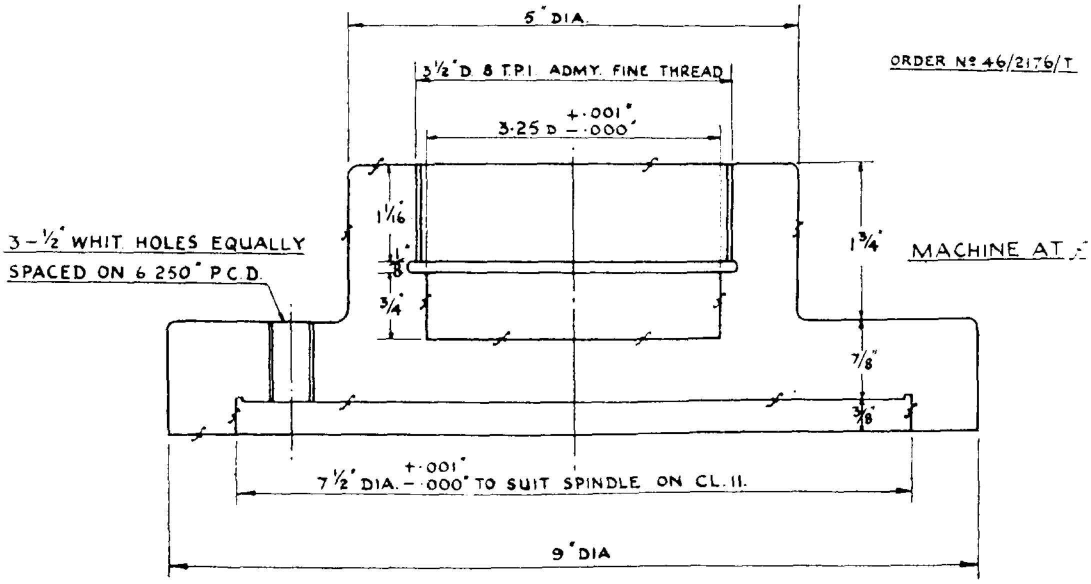
MESSRS. BLANK LTD.
Used on : Turbine Control Valves
Material : Mild Steel

Part No. D.W. 1734173/3
Sheet 1 *of* *Sheets*
Drawing No. 13055B/1

Op. No.	Dept.	Operation	Tools	Gauges	Machine	Time	Setting
1	Stores	Cut billets $6\frac{1}{2}''$ dia. mild steel $\times$ $5\frac{5}{8}''$ long			Circular Power Saw		5 mins. per batch
2	Machine Shop	Hold billet in 3-jaw chuck and clock free end to obtain concentricity within .015	Dial indicator		Med : Centre lathe		
		Face end and centre drill	B. Centre drill Std. facing tool				
		Insert m/c centre and turn 0/D to $3\frac{1}{2}''\begin{smallmatrix}+000\\-002\end{smallmatrix}$ dia. $\times$ $1\frac{13}{16}''\begin{smallmatrix}+005\\-000\end{smallmatrix}$	Std. $\frac{3}{4}''$ roughing tool	4″ micrometer Depth micrometer			
		Turn spigot thus formed to $3\frac{1}{4}''\begin{smallmatrix}+000\\-0009\end{smallmatrix}$ dia. $\times$ $\frac{3}{4}''$ Chamfer $\frac{1}{8}''$ to $3\frac{3}{16}''$ dia.		GO and NO GO Gap Gauge			5 mins. each
		Form undercut to $3\frac{5}{16}''$ dia. $\times$ $\frac{1}{4}''$ wide with $\frac{1}{32}''$ radius	Std. parting tool radiused to suit				
		Screwcut $3\frac{1}{2}''$ dia. 8 T.P.I. Whit. form	55° screwing tool	GO screw ring gauge NO GO major dia. gap gauge			
		Remove centre and drill right through $\frac{27}{32}''$ dia.	$\frac{27}{32}''$ drill				
		Bore to $2\frac{1}{4}''\begin{smallmatrix}+0016\\-000\end{smallmatrix}$ $\times$ $1\frac{13}{32}''\begin{smallmatrix}+005\\-000\end{smallmatrix}$ deep with $\frac{1}{16}''$ rod	Std. boring tool	GO and NO GO plug Depth micrometer			
		Remove burrs. Remove work from chuck					

3	Machine Shop	Screw work from op. 2 into jig to shoulder	Turning jig		Med : Centre lathe		20 mins. per batch
		Face free end to $3\frac{9}{16}''$ from shoulder	Std. facing tool				
		Turn 0/D to $5\frac{7}{16}''$ dia. × $3\frac{1}{16}''$ forming $\frac{3}{4}''$ rad	Std. $\frac{3}{4}''$ roughing tool				
		Drill 3″ dia. (presumed largest stock size) × $3\frac{1}{16}''$ deep	3″ drill				
		Bore to $4\frac{11}{16}''$ + 0013 × $2\frac{3}{8}''$ deep — 000	Std. boring tool	GO and NO GO Plug gauge (Pilot type)			
		Form Recess $4\frac{5}{16}''$ dia. × $\frac{7}{16}''$ deep with $\frac{7}{16}''$ rad.	Std. boring tool				
		Form end fact at 60° from $4\frac{13}{16}''$ dia. × $\frac{3}{16}''$ deep with $\frac{1}{16}''$ rad.	Form tool				
		Drill $\frac{55}{64}''$ dia. and ream $\frac{7}{8}''$ + 0001 — 000	$\frac{55}{64}''$ drill $\frac{7}{8}''$ selected reamer	GO and NO GO Plug gauge			
		Form $\frac{1}{32}''$ rad. at each end of $\frac{7}{8}''$ dia. reamed hole					
		Remove burrs. Remove work from jig					
4	Machine Shop	Locate on an indexing jig and mill 4 slots $\frac{3}{8}''$ wide × $\frac{1}{4}''$ deep	Milling jig $\frac{3}{8}''$ sided face cutter		Horizontal milling m/c		20 mins. per batch
		Reset jig and mill end slots $\frac{1}{2}''$ wide × $\frac{3}{4}''$	$\frac{1}{2}''$ sided face cutter (radiused)		do.		
		Remove from jig and remove burrs					
5	Inspection Dept.	Inspect in accordance with Inspection Layout No. 0000					

NOTE : Component machining times are omitted as it is not possible to specify particular machines on this specimen planning sheet and therefore speeds and feeds are not known.



C.I. TURNING FIXTURE. 1-OFF.

FIG. 2

TABLE II

CONTROL VALVES
VALVE CAP

DRG. No. 13055B — DESCRIPTION
DATE 27.6.46 — No. PER SET

LAYOUT No. 569
PATT. MARK
SHEET No. 1 of 1
MATERIAL MS. BLANK
ISSUE 1
WKS. ORDER No. 46/2176
TOOL ORDER No.

Dept.	Op.	Description of Operation	M/C	Tools, etc.	Estimated Time
		Receive blanks from Stores			
	1	Rough turn and bore $5\frac{7}{16}$″ end then finish turn screwed end	C.L.11	G39539, G5–323, Mics 2–3, 5–6	
		Screw Gauge		G6–381	
		Leave .875″ bore to finish with 4.6875 bore			
	2	Then finish turn and bore $5\frac{7}{18}$″ end 4.6875″ bore	G.L.11	T.F.217 (Fig. 2), G1–525	
		.875″ bore		G1–293	
		Concentricity gauge		G1–524	
		NOTE: No eccentricity allowed			
		Must be first class job			
		Remove burrs			
	3	Drill 8—$\frac{3}{8}$″ holes $2\frac{7}{8}$″ P.C.D.	R.D.4	D.602, $\frac{3}{8}$″ drill	
	4	Mill 2—$\frac{1}{2}$″ and 4—$\frac{3}{8}$″ slots	V.M.12	Dividing head	
		Set to drilled holes		$\frac{1}{2}$″ end mill	
		Remove burrs		$\frac{3}{8}$″ end mill	
		Inspection			
		Stores			

(17366) Wt. 35769-P6582 4000 2/48 G.S.St.