OPERATING CONTROL TECHNIQUES

By S. E. SOHLER

THE meaning of operating controls in the aircraft industry is best expressed by their three basic principles:

1. The operating plan of action must consider all limiting factors and be possible of attainment as a total program as well as for individual projects.
2. The operating plans, including policy instructions where applicable, must be transmitted to concerned personnel throughout the organization in adequate detail.
3. Progress information must be available with sufficient speed, coverage, and competent evaluation to provide a basis for intelligent action at all levels of supervision.

The true test of manufacturing management's ability is the devising and revising of operating control techniques to meet changing conditions effectively and efficiently.

Because of space limitations, no attempt will be made in this article to cover the many phases of operating controls involved in a major aircraft plant. However, two typical control problems encountered at the California Division of North American Aviation, Inc., during the war will be described, along with the operating control techniques which were developed at that time and which have been used to advantage on similar problems since.

The philosophy behind the development of these techniques is expressed by the following motto, which occupies a prominent place in the office of one of the foremost aircraft executives: "It may not always be the best policy to adopt the course that is the best technically, but those responsible for policy can never form right judgment without knowledge of what is right technically."

This type of approach is especially cogent in the aircraft industry, where the complex problems involved, combined with the so-called "human element" in the many people concerned, make complete dependence on theory and statistics impractical, and make operations without them almost an impossibility.

TOOLING

A. Problem

The problem of tool loading was a chronic headache even during the pre-war period, when contracts were small and comparatively little tooling was justified. Whenever the tool shops appeared to be overloaded, the problem was usually overcome during a comparatively short period by working overtime and Saturdays, or even hiring a few additional tool-makers temporarily. However, wartime conditions made some form of control necessary for several reasons:

1. Contracts were much larger and, therefore, much more elaborate tooling was justified. Most of this elaborate tooling had to be completed for the first ship, unless there was adopted the very expensive alternative of building temporary tooling for the first ship and replacing with permanent tooling later.
2. As tooling departments were already working 50 to 60 hours per week and tool-makers were very scarce, any overload condition could not be appreciably alleviated by additional overtime or additional hiring.
3. Many more production workers were dependent upon the tools to be made than ever before, especially because of the inexperience of production department labor available. In view of the labor shortage, idleness of productive labor resulting from lack of tooling could not be tolerated.

An analysis of past experience showed that the tooling shortages usually become critical during the last 30 to 60 days prior to completion of the first ship. The reason for this became apparent when the total of tooling hours required for the basic tooling on the first ship was plotted against a time scale, with the distribution of these hours based on the assumption that all tools were

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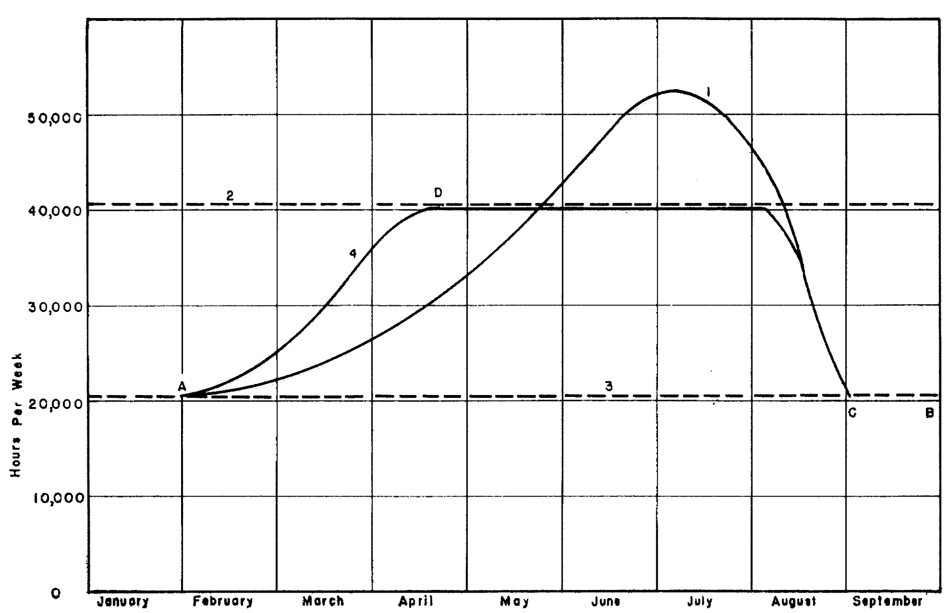
FIG. 1
Tooling load chart.



					Shown are total accumulative hours expended												
Part Number	Tool Number	Tool Name	Date Order Issued	Acct.	3-1	3-8	3-15	3-22	3-29	4-5	4-12	4-19	4-26	5-3	5-10	Total Hrs. Est.	Adjust Hours Est.
175-24678	87491	MP	2-7	8321	53	75	126	—153	—178							175	200
175-28671-1	88421	ADJ	1-3	8321	30	46C										50	
175-34878	88215	ADJ	1-20	8351	0	10	30	37C								35	
175-58764-1	87465	TWJ	2-10	8321	40	58	80C									85	
175-48226	181681	DP	8-18	8311	6	13	22C									18	
175-24004	181683	DJ	8-20	8311	0	0	0	25	50C							50	
175-24409	182606	DJ	8-22	8311	20	23	23	46	—80							88	
175-22410	182610	DJ	8-23	8311	0	0	25	50	—50							100	
175-22409	182608	DJ	8-22	8311	10	35	65	75	—90							100	
175-24410	182609	DJ	8-23	8311	0	0	0	50	—80							130	
175-21601	183184	DJ	10-8	8321	0	0	0	12	25C							25	
175-23403-3&4	183231	DJ	10-2	8321	15	20	25	50	—50							60	
175-22316-3	181895	DP	8-21	8311	0	0	10	20	30							60	
175-34557-3	183118	D&RJ	10-2	8321	10	20	25	30	40C							40	
175-31813	183156	DJ	10-21	8333	3	6	10	15	20C							20	
175-22505-6	181631	DJ	8-23	8554	0	0	0	0	0							10	
175-22405	181361	DP	8-20	8331	0	0	10	12	14							16	
175-33589	183105	PF	10-1	8321	2	10	12	15	18							23	
175-16106	181632	MF	10-21	8311	0	0	10	20	45							50	
175-56006	182908	DJ	8-31	8311	0	15	35	65	75							75	
175-33589	181633	DJ	8-31	8331	10	15	15	25	30							45	
175-52753	182620	DF	9-26	8331	0	0	0	10	10							30	
175-33104-1-2	183626	ApDJ	10-2	8331	0	0	2	8	10							60	
175-52753	181718	DJ	9-6	8321	0	0	0	0	0							40	
175-52466	181715	DJ	10-2	8321	0	5	5	5	5							30	

Dept. 14 — Group No. 2 Singleton — WEEKLY TOOLING COMPARISON SCHEDULE, North American Aviation, Inc. — Contract NA-175 — Note: Heading on vertical column denotes due date of tool.

Fig. 2

to be constructed just in time to meet the true required **completion date** of the tool as needed to support the **"in-work" date** of the part or assembly involved. (See *Fig. 1*, Curve 1.) Curve 2 in the illustration indicates the total anticipated tooling capacity over the period considered. Curve 3 indicates the portion of that capacity already allocated to other projects. In actual practice these two lines would normally vary during such a period, but they have been shown as fixed values for the purpose of simplifying this example. Point *A* indicates the date on which sufficient engineering information was available to enable tooling hours to be started. Point *B* indicates the tentative date set for completion of the airplane, and Point *C* indicates the date by which the basic tooling for the airplanes had to be completed in order to support that completion date. From this graph it was immediately apparent that tooling shortages during the 30 to 60 days prior to airplane completion were inevitable if all tools were started just in time to meet the completion date, as there just wasn't enough capacity available during that period to expend the hours required. The control problem then became one of devising a means of insuring that enough tooling hours were expended early in the project to complete all basic tooling by the required time. The other alternative, increasing and decreasing of the capacity to conform to the load represented by Curve 1, was impossible under conditions of wartime labor shortage.

B. Solution

The first step was to redistribute the total basic tooling hours required over the period between Point *A* and Point *C* in such a way that the load would not exceed the available net capacity. (See *Fig. 1*, Curve 4.) Such a plan required that the expenditure of tooling hours reach a maximum by the date indicated by Point *D*, and a check was made of the engineering release schedule to determine whether or not sufficient engineering information would be available for the tooling departments to support such a plan. If not, the completion date of the airplane was set back, or the tooling policy was revised to call for less permanent tooling for the first ship. This investigation and planning satisfied the principle of making sure that the total plan of action (including all other commitments), as well as the plan for the specific project, was physically possible.

Satisfaction of the second principle of operating controls (transmission of the plan) presented additional problems of technique. Two possibilities were available:

1. Rescheduling of sufficient tools from their true due dates to earlier due dates, such that the distribution of the hours load per schedule corresponded to Curve 4.
2. Leaving the true due date on each tool, and through some other device insuring that the tool departments expended hours on this project in accordance with Curve 4.

The first possibility had several inherent **disadvantages**:

(a) Giving specific tools due dates appreciably earlier than their true dates tended to lessen the shop's confidence in the dependability of schedule dates, especially if tooling supervision were on occasion chastised for missing due dates on rescheduled tools which it could individually prove weren't really needed for six or eight weeks.

(b) There was a possibility that the engineering department would not meet its own release dates on those specific parts for which specific tools had been rescheduled earlier.

Therefore, it was decided that the due date to be used on individual tools would in every case be the true due date as actually required by the master schedule for the first ship. In this way, confidence of the individual tool-maker in the schedule was not impaired, and a behind-schedule tool obtained priority treatment for reasons that were provably valid. The plan of action for the project, when issued to tooling supervision, included a curve similar to Curve 4, along with an explanation of the need for the expenditure of hours in accordance with that curve. This device also made unnecessary the risk of out-guessing engineering, as tooling departments merely expended hours on whatever information was available early, so long as the total expenditure conformed to Curve 4.

In addition to the due date on the tool order it was found advisable to prepare a so-called weekly comparison schedule (*Fig. 2*) which kept a summary of current tool orders by due date in front of all levels of supervision, along with the estimated hours required for the construction of the tool, and the actual cumulative hours expended on each tool to date. This type of schedule was for the purpose of satisfying the first and second principles at the same time, with a minimum of clerical effort.

The third principle of operating controls was also satisfied in this case by a weekly comparison between Curve 4 and the actual weekly hours' expenditure during the early phases of the project, along with an analysis of the reasons for any deviation. This was subsequently supported by the weekly comparison schedule noted above, during the latter phases of the project, when individual tools became due.

PLANT CONVERSION

A. Problem

Early in 1944 the Army indicated a desire for increased quantities of P-51's, which were currently in production at the California Division at 10 per day. However, in view of the manpower shortage it was agreed that an increase could be accomplished only by discontinuing the production of B-25's, which were currently running at five per day, but which were also being produced in appreciable quantities at North American's Kansas City plant. Thus, it became management's problem to plan and execute an orderly and efficient conversion of the California Division plant from B-25's plus P-51's to full P-51 production, starting with the following basic factors:

1. A total of approximately 10,000 direct workers was employed, with 6,000 working on the P-51 and 4,000 on the B-25.
2. Employees were quitting at the rate of 200 to 300 per month and new hires were not quite able to keep pace with this turnover rate.
3. The B-25 project occupied the larger of the two final assembly high-bay areas, and the P-51 had to be moved into this area before production rates could be appreciably increased. Also, supporting P-51 major assembly departments had to be relocated or expanded, or both, to provide the additional capacity necessary.
4. Duplicate tooling would be required on most major assembly jigs and on some subassembly jigs. This problem included the determination of which assemblies would need any duplicates, how many would be needed, and when they would be required, as well as the finding of tooling capacity to construct them.

A preliminary survey indicated that it would take approximately three weeks to convert the B-25 area to accommodate the P-51 project. In other words, for a three weeks' period hundreds of employees working on the B-25 would be available, but the P-51 production rate could not sufficiently increase in its existing area to use all the capacity thereby made available. Any attempt to lay off these employees for this period and subsequently rehire them was out of the question, in view of the already high turnover rate and the difficulty of obtaining new employees. On the other hand, merely allowing these employees to stand around during that period would be very bad on morale, to say nothing of the wasted effort involved.

B. Solution

The satisfaction of the first principle of operating controls required considerable investigation and analysis because of the many factors involved. The first step was to reexamine the conversion plans, which, in the preliminary survey, were estimated to require three weeks in the critical final assembly departments. By specifying the maximum prefabrication of conveyor line structure and equipment, and by planning that the actual construction work in the B-25 area take place station by station immediately following the last airplane as it went down the line, the planned final assembly conversion time was cut to 10 days.

An analysis of the operations in the P-51 final assembly area was made, showing that by "supercharging" or over-manning each station with some of the personnel released from the B-25 final assembly, a temporary production rate of 14 per day could be obtained while the P-51 project was still located in its original area. Also, production rates above 14 per day were planned for the P-51 as soon as possible after the scheduled relocation into the larger area. On the basis of the production schedules arrived at in the manner described above, a total direct labor load was computed for the period involved in the conversion. (*Fig. 3*, solid lines). This total labor load for the factory assumed normal distribution of hours' expenditure prior to airplane completion; i.e., it assumed that hours would be expended on parts and assemblies as actually required by the next assembly or by the final line and with normal minimum storage time allowed. In anticipation that some net loss of personnel would be inevitable as a result of this conversion, the maximum P-51 scheduled rates were set at a level which would not require a peak load in excess of 9,500 direct employees, the most optimistic figure possible under the circumstances, as normal turnover rates would easily bring about this reduction during the two months that no new hires would be taken on. The gradual decrease of employee requirements beyond the peak of 9,500 was a recognition of the hours per unit improvement that would be experienced after the maximum production rate (20 per day) had been attained.

It was immediately apparent from this graph that some additional action would be required to avoid the necessity of a layoff or a period of mass idleness. A reexamination of employee turnover experience indicated that termination rates appreciably higher than average could be expected during the conversion to full P-51 production, as the reorganization of departments and the regrouping of personnel were certain to result in many dissatisfied employees who were merely waiting an excuse to quit. Therefore, it was decided that plans were to be based on the assumption that approximately 1,000 direct workers would be lost as a result of the conversion. The tentative final assembly completion schedules mentioned above, which had been based on the physical limitations of the areas involved, were left intact, and it was assumed that the volume of work represented by Area *A*, *Fig. 3*, could be rescheduled to take

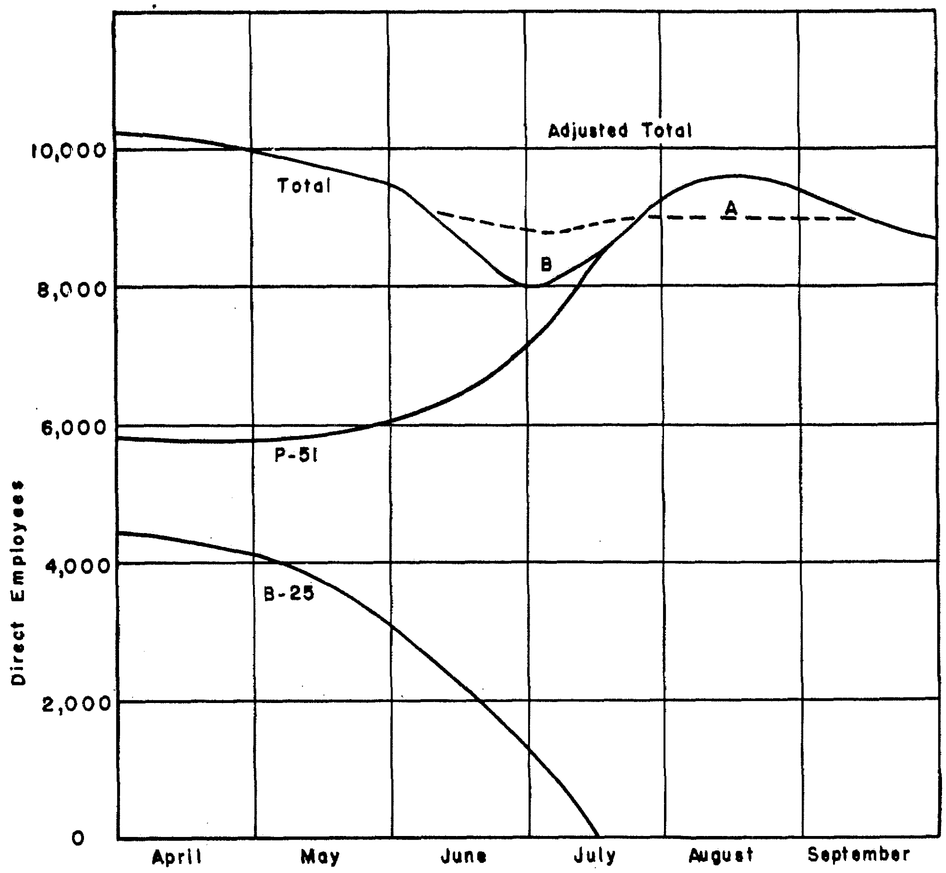


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FIG. 3
P-51 and B-25 labor loads for conversion period.

place earlier, as indicated by Area *B*. The following plans were devised to carry out such a program:

1. The problem was comparatively simple in those detail and functional subassembly departments which had been fabricating both B-25 and P-51 parts. It merely required that sufficient additional P-51 parts be scheduled into those departments immediately behind the end of the B-25 contract, such that the full capacity of the departments would be used. This meant that an appreciable number of P-51 detail and subassemblies would be fabricated prior to actual need, and arrangements were made to provide storage area for these. The schedule was so adjusted that this excess of parts was gradually absorbed during the four to five months after the conversion, by which time all schedules were faired back into line on a normal minimum storage basis.
2. The plans temporarily to "supercharge" the P-51 final assembly lines prior to moving were rechecked and left as described above.
3. In the major assembly departments supplying final assembly, a similar temporary "supercharging" was planned. However, in some major assembly departments, such as those building wings, flaps, control surfaces, etc., it was planned that inefficient "supercharging" would be avoided as much as possible by specifying that the production of spares be temporarily stopped and the 14 per day rate required to support final assembly obtained by temporarily diverting that spare capacity to production parts. It was intended that the behind-concurrency status of spares production resulting from the action described above would be compensated for at a later date by increasing the production rate to a maximum in those departments prior to the time final assembly schedule production rate had reached maximum. This concentration on major assemblies for final assembly actually had to start several weeks prior to the time the final assembly rate went above 10 per day, in order that additional assemblies would be on hand by the date the stationized conveyor lines were moved. This additional supply of major assemblies had to be available to fill the increased number of stations in the new conveyor line layouts. Only by filling these stations immediately after the move, could the excess final assembly personnel be kept busy at the earliest possible moment and the production rates increased quickly thereafter to use up the backlog of stored details and subassemblies.

The plans described above were laid out for each department and a load chart similar to *Fig. 3* prepared for each. When totaled, these charts closely corresponded to the desired total load as expressed in *Fig. 3*, and the plan of action for production departments was approved by management.

4. After all departmental production schedules had been established in the manner described above, the current hours-per-unit reports were consulted to determine those jigs on which one or more duplicates would be required to support 20 per day plus spares, and a chart plotted for each, indicating future production rates, including spares. (See *Fig. 4*). On each of these charts there were plotted the dates on which each duplicate would be required to meet the increased rates, using current unit hours as a basis for this decision. (*Fig. 4, A.*) In the case of major jigs

involving a considerable expenditure of man hours, a careful check of the hours per unit expended on that item during the last several months was made, and if appreciable additional improvement on hours per unit could be anticipated, such a consideration was used in deciding whether or not all of the duplicate jigs would actually be necessary. In a surprisingly large number of cases it was found that some of the additional tooling required on the basis of current hours per unit would not actually be required by the time maximum production rates were scheduled, because of the justifiably expected improvement in unit hours performance which would be obtained by that time. *(Fig. 4, B)*. Individual duplicate tooling requirements determined in the manner described above were then extended into a total man hours load, and this in turn added to the known loads on other projects in the tooling departments. In this particular case, no adjusted hours load curve had to be used, but, if necessary, the control device described in the first section of this article could have been used.

The second principle of operating controls was satisfied as follows:

1. In accordance with normal practice, all detail part work orders had been given in-work and completion schedule day numbers prior to issuance to the shop. The temporary acceleration of P-51 detail fabrication schedules then merely required the adjustment of the conversion chart between schedule day numbers and calendar dates. This revised chart was issued to all stockrooms and control stations handling detail work orders.
2. As all assemblies were already scheduled individually on a weekly comparison schedule form, of the same general type as the tooling comparison form described in the previous section, the specific plans for each assembly department were quickly and accurately expressed to all personnel concerned.
3. Departmental rearrangement plans were plotted on a master chart by industrial engineering, all the timing was checked for proper coordination, and specific detail move notices were issued to cover each area involved.

The third principle of operating controls was satisfied principally by the existing progress reporting mediums, such as work order status in detail departments and weekly progress reports in the assembly departments on the comparison schedule form mentioned above. Tooling progress was followed on the tooling comparison report described above. Additional special follow-up on the conversion work was instituted and closely watched.

As a result of the operating controls described above, the last B-25 was completed on schedule to the minute. On a Saturday and Sunday, nine days after the last B-25 had been completed, the P-51 final assembly department was moved to the converted B-25 area. On Monday, 14 P-51's were completed off the new line, and this rate was increased to 16 per day one week later, as planned. As a result of the manpower controls used during this period, the unit cost of the P-51 rose only two per cent, and that for a period of only two weeks, after which the previous improvement trend continued. The conscientious adherence to the principles of operating controls had paid off a thousandfold in relation to the development and maintenance expense of an organization to provide those controls.

Wins Legion of Merit

COLONEL JAMES BOYD, former professor of mining geology at the Colorado School of Mines, and now United States Director of Industrial Production in Europe, recently was awarded the Legion of Merit for success in initiating and developing materials control and the procurement of metals and minerals for the Armed Services.

Colonel Boyd was a staff assistant to the director of materiel in the headquarters of the Army Service Forces between March, 1942, and April, 1945, during which he "was responsible in large part for the successful operation of the entire system of allocation by the War Production Board of critical raw materials in such manner as to assure a maximum war effort."

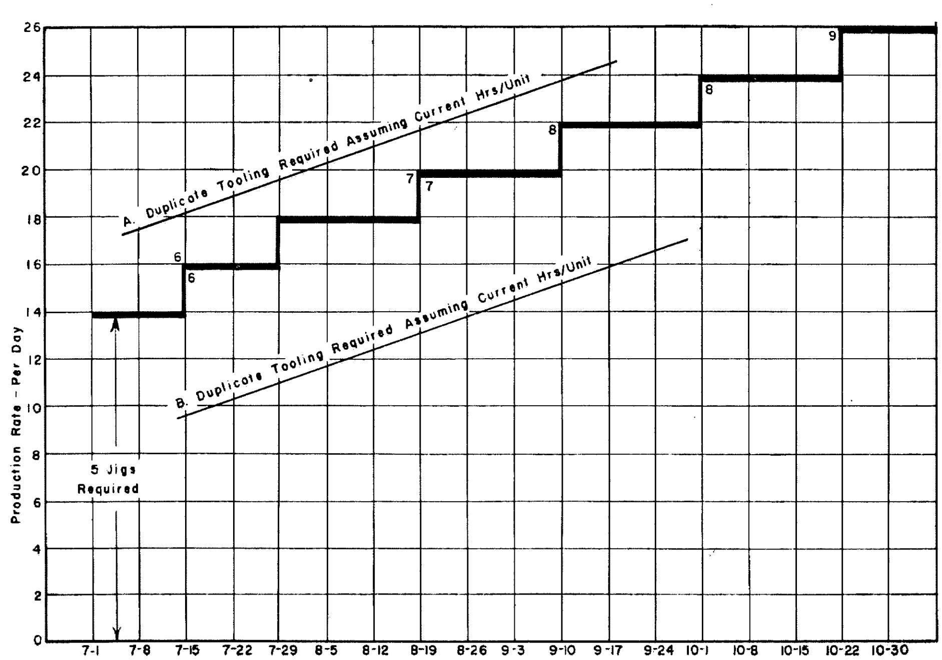

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FIG. 4
Typical duplicate tooling survey sheet showing effect of employed hours per unit.