

PRODUCTION SCHEDULING ON A NATIONAL BASIS

6 December 1946

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THE INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D.C.

RESTRICTED

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PUBLICATION NO. 147-48

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PRODUCTION SCHEDULING ON A NATIONAL BASIS.

6 December 1946.

CAPTAIN WORTHINGTON:

It is a pleasure this morning to welcome Mr. William K. Frank to The Industrial College.

Mr. Frank is a graduate of Cornell University with the degree of Mechanical Engineer, which he received in 1911.

In the period 1911 to 1926 he served in various capacities from chemist to general manager of the Damascus Bronze Company. In 1926 he left the Damascus Bronze Company to accept employment with the Copperweld Steel Corporation. His career with this company has been a series of successes and promotions. At the present time he is the president of the corporation.

In October of 1941 he was called to Washington and the government service with the Office of Production Management, where he served as consultant on production problems. In July of 1942 he was made chairman of the Resources Production Board of the War Production Board. In November he was appointed deputy director of the General Industrial Equipment Division of the WPB, and in December, 1942, became the director of that division. In September, 1944, he was appointed technical advisor to the Industrial Equipment Requirements Section, and in June of 1945 became a special assistant to the Director of the War Production Board.

With the termination of hostilities, he returned to the Copperweld Steel Corporation to resume his duties as president of the corporation.

The subject of his lecture is "Production Scheduling on a National Basis." Mr. Frank.

MR. FRANK:

Gentlemen, this subject of production scheduling is something very close to my heart. As you know, we were in bad trouble early in the war. We got out of it only through production scheduling.

It soon developed in World War II, that usually 10% of the manufacturers shipped 90% of the product. For instance, if there were 100 manufacturers in the industry, the ten largest accounted for approximately 90% of the production. Accordingly, the War Production Board concentrated on these ten largest for detailed scheduling and required only general reporting from the other ninety. This reduced paper work tremendously and in general was effective control.

The information needed from each manufacturer was as follows: An advance estimate of monthly productive capacities--orders received during the month - orders shipped during the month - orders cancelled during the month - and unfilled orders at the end of the month. When the unfilled orders of an industry were rapidly accumulating, we knew there was trouble ahead, and when they leveled off or were shrinking, it could be expected that that industry was getting out of trouble. In the industries where production was changing, a good barometer was to plot the number of months represented by the unfilled orders in terms of the most recent production. It will be seen that in the case of rapidly expanding productions, even though the unfilled orders might be rising, the months of backlog might actually be falling.

Information needed from the claimants for proper scheduling include the following: quantities, type, accurate delivery date requirements, and name of manufacturer where possible. As will be realized, this was a task of tremendous proportions for such large claimants as the Army and Navy. However, many branches of the Services did a perfectly amazing job of knowing their requirements in great detail down to the last sub-component.

Outstanding examples of detailed knowledge of components were in the two landing-craft programs. The success of these programs was undoubtedly due to detailed knowledge, and can serve as a model for future operations. I cannot press too strongly on this point of detailed knowledge.

To get rapid war production it is necessary that the Services accumulate in peacetime bills of materials and be so organized that additional bills of materials can be secured and tabulated quickly.

The year 1942 was a critical year in production. It was in this year that trial and error produced organizations and mechanisms that were to stand for the balance of the war. It was during this year that the solution was found of relating requirements to the available resources of the nation. At the top level the problem of long range programming involved the collaboration of the President, the Joint Chiefs of Staff, and the Chairman of the War Production Board. The next step was the breaking down of the long term production goals into quarterly or monthly goals and the parcelling out of the resources in order to achieve the approved goals. The principal mechanisms created in 1942 to handle the problems of this level were the Requirements Committee in the War Production Board devoting primary attention to materials, and the Production Executive Committee devoting primary attention to program scheduling. The last step in this chain was the actual flowing of the materials, components and equipment to the individual industrial plants that needed them.

By the fall of 1942 it had become evident that the nation had been working upon a set of production objectives for 1942 that had more than doubled since the beginning of the year. They were well beyond the practical limit of feasibility, and it was decided to concentrate resources

and energies upon a "do-able" proportion of the program. The Production Executive Committee was established and included with Mr. C.E. Wilson as Chairman, representatives of the Armed Services, and the U.S. Maritime Commission. It was made responsible for the scheduling of the various production programs of the Army, Navy, Maritime Commission and others, in order to insure that the schedules would not conflict and were consistent with the maximum productive possibilities of the national economy, and were in accordance with the strategic requirements of the Chiefs of Staff.

Component Scheduling

A sub-committee--the Committee on Production Scheduling--was established, again with representatives of the War Production Board, the Armed Services and the U.S. Maritime Commission. This Committee concerned itself principally with scheduling of components and particularly with a list of 34 critical components.

General Scheduling Order M293

It was decided to incorporate all of the critical components into one scheduling order so that there would be uniformity of treatment in all matters.

This led to the issuance of General Scheduling Order M293, on 27 February, 1943.

The components listed were classified in 3 categories, "X", "Y" and a third unlabeled group. Manufacturers of products within the "X" group were required to (1) submit a regular operations report showing productive capacity and orders unfilled, received, shipped, cancelled, and scheduled for a specific period prescribed in the form applicable to the particular component; (2) report delivery schedules for the specified period; (3) deliver components only under the schedule as approved by WPB. Once filed, the schedule was to be followed regardless of preference ratings or directives. These were "frozen schedules", to be changed only by the Industry Division.

The "Y" classification, containing only 7 types of items, included the most critical components. Almost all were already under existing scheduling orders. Persons seeking to place an order for any component in Class "Y" would first have to receive specific authorization from WPB, which would specify the manufacturer with whom the order was to be placed. Having been given such an order, the manufacturer would make delivery in accordance with the schedule regardless of preference ratings of other orders.

The undesignated category contained the least critical of the components listed in the order. Manufacturers involved in this category were required to submit only a regular informational report to the Board.

During the succeeding months Order M293 was generally well received by industry, the claimant agencies, and the public. In most cases, once the components had been scheduled, the shortages disappeared.

By late spring 1943, the administration of M293 was smooth, and the general problem of component supply was considerably relieved, the exceptions being steel valves, heat exchangers, and aircraft control instruments.

In the fall of 1943 an additional category was added to M293, this being designated as "Z" category. The "Z" procedure was designed to (1) identify orders of the programs with the end-use at each contracting level; (2) establish shipping dates in harmony with the building schedule of the end-product or project; and (3) freeze shipping schedules of certain orders without sending the complete order boards to Washington. The procedure was mandatory when initiated by certain claimant agencies. Limited to 16 control components and 8 sub-components, it was strongly opposed by industry advisory committees. It was tried out on the ship program of the Army Transportation Corps. Manufacturers believed the procedure would not accomplish its purposes and they resented the added paper work involved. Their protests were heeded and the procedure was amended in early 1944.

Component Scheduling Procedure

A task committee composed of representatives of the Armed Services and WPB had been working on a revision of scheduling procedures, and in June, 1943, Component Scheduling Procedure (CSP) was announced for certain selected groups of programs. The plan sought to require claimant agencies and their prime contractors to program for several months in the future, indicating their requirements for control components to the full extent of the future program. Control component manufacturers were expected to indicate their promised delivery schedule against the required delivery schedule presented to them. This form flowed back to the prime contractor and was returned to the claimant agency.

CSP was to achieve only moderate success. The plan involved added burdens of paper work and industry representatives were disposed to regard it as a highly theoretical device. It soon became apparent that under this arrangement the greatest difficulty facing component producers was their inability to place their orders for controlled materials until they themselves had received orders for their products. The time lag was too great for efficient production.

Control of Materials

Until late in 1942 it was materials rather than facilities, components or manpower that seemed to be the basic resource through which controls of the productive process could be achieved. Plant capacity was not a seriously limiting factor in achievement of high production goals. Components did not constitute the major limiting factor in

production until the fall of 1942, and machinery for controlling the flow of components was not fully matured by the end of the year. Manpower had not yet emerged as an acutely limiting factor. Materials therefore appeared to be the clue to the achievement of the production program. Through the control of the flow of materials it appeared possible to control the rate of production and the kind of production in practically all important plants of the country. The year 1942 started with a variety of material distribution controls, including individual preference rating certificates, blanket preference rating orders, allocation schemes for particular materials and the Production Requirements Plan, known as "PRP". Preference ratings had by 1942 become wholly inadequate as the principal control over the flow of materials. They were qualitative ratings with no quantitative limits; they were valuable only so long as the materials for which they were used were in relatively plentiful supply; the same preference rating had a variable value to the manufacturer as he applied it to a succession of materials, each of which had a different degree of shortage, and the preference rating currency was progressively cheapened, as all producers sought to obtain higher ratings as they discovered their existing ratings were worthless in procuring materials.

In addition to the preference rating system there was also a group of allocation schemes for particular materials. The virtue of any allocation scheme was that it defined the quantities of materials to go to any particular user and operated within the limits set by available supply of the materials. Individually operated allocation schemes, however, had two basic flaws. The material branches of WPB did not feel bound to adhere strictly to the preference rating system, since this system was in disrepute and was not regarded as an accurate indication of the importance of the particular use of materials to the war effort. The second principal objection to controlling the flow of materials through individual allocation systems was that each system operated autonomously under a particular WPB materials branch, with the result that coordination in the flow of materials was lacking.

Production Requirements Plan

Along with the preference rating system and allocation schemes, the year started with a portion of industry voluntarily under PRP. PRP wedded the preference rating system to the allocation idea and added the principle of coordinating the allocation of all important materials to assure a balanced flow to the manufacturer. It further related authorizations to inventories of the applicant.

PRP was made mandatory for the third quarter of 1942. All industrial consumers of basic metals were required to apply each quarter for preference ratings covering their requirements for those metals. Requests were to be balanced against supply and based on end-use; preference ratings--limited as to amounts of materials--were issued to the applicants. This was a "horizontal" allocation plan, in that the authorizations passed directly to the user of the materials, as contrasted with a "vertical" plan in which the authorizations passed to a claimant agency,

then followed down to the prime-contractor and then down to and through a chain of subcontractors.

The searching about for a master control system continued, revolving about the relative merits of "horizontal allocation" and "vertical allocation", principles that constituted the cores of respectively the Production Requirements Plans, the Controlled Materials Plan. Had the total demand for materials been brought in balance with the supply, the shortages encountered by particular manufacturers under PRP would not have occurred. The difficulty stemmed from the fact that authorizations always greatly exceeded the production of materials. A feasible program, advance control of the placement of orders, and a stricter control of production scheduling were all identified at the time as essential prerequisites to the operation of PRP. All of these issues were not settled until the fall of 1942 or later, and PRP was being asked to solve problems that were beyond the capacity of any scheme designed merely to guide the flow of materials through industry.

Despite the shortcomings of PRP this was the system that provided the basic flow of materials through the third and fourth quarters of 1942 and the first quarter of 1943. In the second quarter of 1943, when the transition was being made to CMP, PRP authorizations continued to be partially effective. This period from July, 1942, to March, 1943, and in part to June, 1943, was in many ways the most crucial in the battle of production. The great rise in production which was to reach its war-time peak in the fall of 1943 was coincident in large part with the PRP method of controlling the flow of materials. It was realized that the budgeting of materials could not really be effective without a comprehensive scheduling of at least the most important programs, particularly the important military programs such as shipbuilding, plane production, and ordnance. With such scheduling and the consequent evaluation of quantities and needed times for materials, either a horizontal allocation system or a vertical allocation system would prove effective.

Controlled Materials Plan

However, the advocates of vertical allocation capitalized on the apparent failure of PRP, and on November 2, 1942, after all government agencies concerned had reached an agreement on the fundamental principles, Controlled Materials Plan was publicly announced. CMP was designed to make certain that production schedules were adjusted within materials supplies. This end was to be accomplished by adjusting requirements of the controlled materials---copper, steel and aluminum---to the available supply, and then making available at the time needed the types and amounts of these materials necessary to meet the various programs scheduled under the plans.

Under the vertical allocation system provided by CMP, the Requirements Committee of WPB held the material purse-strings, receiving applications from and making allotments to the various claimant agencies--Army, Navy, Maritime Commission, Lend Lease, Office of Civilian Supply,

etc. (Eventually there were some 13 claimant agencies covering the whole economy.) The claimant agencies would then allot to their prime consumers, and the secondary consumers--suppliers to prime consumers--would receive their allotments of controlled materials from a prime consumer or from another secondary consumer.

"Class A" and "Class B" Products

The products manufactured with controlled materials were classified as "Class A" products, and "Class B" products. "Class B" products were intended to be those items normally sold on the open market and those sub-assemblies or miscellaneous or specialized items of equipment for which individual specific allotments to prime consumers were deemed impractical. In a loose sense "B" products were shelf items containing controlled materials and used for a variety of purposes, both military and civilian. Among typical examples were bearings, bolts, nuts and rivets. "B" products were listed. All other products were "A".

As the CMP evolved, a manufacturer of "B" products made his application to and obtained allotments from the appropriate WPB industry division. Each claimant agency presented its claims for "B" items to the industry division and the Divisional Requirements Committee reconciled requirements with respective supplies of "B" items and translated the approved requirements into their gross materials content. Each claimant then included the appropriate portion of such material requirements with his requirements for "A" items and submitted these statements to the Requirements Committee. The Requirements Committee in turn would allocate to all claimant agencies all materials required for both classes of items, within the limit of supply, and the claimant agency would then notify appropriate industry divisions as to the "B" products for which it was making a part of its material available.

There was no more difficult problem under CMP than the determination of the classification of items as "A" products and "B" products. This went to the heart of the control system. CMP had been announced as a vertical allocation plan but it had been recognized that vertical allocation was not the appropriate method for distributing materials to all manufacturers. A portion of the total supply of materials would have to flow under the horizontal allocation system to producers of certain products. The greater the length of the "B" list, the less would CMP be a vertical allocation system. WPB was caught between two fires---on the one hand, it wished to keep the number of "B" products down in order to achieve the many advantages of vertical allocation, chief of which was the tying of manufacturers' production schedules to end product programs, and the close coordination of materials allotments with the approved production schedule. It however was evident that the manufacturer at the bottom of a long chain of subcontractors who was the last to receive his allotments was on the other hand the one who was required to make the first delivery in order to start the assembly chain. It was pointed out by an electric motor manufacturer that it was necessary for them to estimate prospective orders and order and receive materials long before they received actual orders. Further, in order

to have runs of practical quantities, it was necessary to "basket" orders. If allotment of materials was to follow orders, the production cycle would be lengthened far beyond the time ordinarily expected by their customers.

The pressures for shortening and lengthening the "B" list continued through 1943, and into 1944. In the middle of 1943 approximately 75% of the controlled materials were being allotted to "A" products and 25% to "B" products. At the beginning of 1944 it was announced that all except approximately 20 "B" items would be handled as "A" items to the extent that they were involved in scheduled production programs of procuring claimant agencies. In practice the procurement claimant agencies found that except for a few items where the contracting chain was relatively short it was more practical to secure their requirements as "B" items and they continued to furnish the industry division of WPB materials to allot to manufacturers as heretofore.

The functions of the operating divisions of WPB included the compilation of estimates of supply and demand, the production and distribution of the products of the industry, in accordance with program determinations, and the authorization of the purchase of materials and products by the industry. The industry division was responsible also for expanding the supply, curtailment of less essential consumption, and the assuring of optimum utilization of the industry, as necessary to meet essential war demands. In each industry division was a divisional requirements committee, chaired by the division director, on which were representatives of each of the major claimants. The division had the services of industry and labor advisory committees, and officers assigned by the Armed Services to serve as the channel between the Services and the division. It was in the industry divisions that the scheduling of materials and "B" products was performed.

The methods employed were as various as the products dealt with, but the following few examples with minor variations fairly cover the range.

Hand Scheduling Compressors

Early in 1942 it was becoming evident that we faced a problem in large compressors, required for new facilities then being planned for the production of ammonia and toluene for explosives, synthetic rubber, aviation gasoline, oxygen, and the like. In attacking this problem the procedure outlined at that time was as follows:

1. Secure from the various agencies detailed information of requirements, and from manufacturers their capacity to produce.
2. Examine order books of manufacturers to determine which orders have been placed.

3. Review expansions already authorized and determine need for additional expansions.
4. Develop new sources of manufacture.
5. Assist manufacturers in expediting expansions, securing materials, preference ratings, subcontracting, financing, etc.
6. Review order books, re-examine scheduled delivery dates of existing orders, and reschedule them after investigation of the indicated present needed dates.
7. Check availability of existing compressors.
8. Check possibilities of furnishing larger number of smaller units for certain requirements.
9. Investigate advisability of placing pool orders and, if advisable, determine the numbers and types to be ordered.
10. Appoint Advisory Committee of Industry.
11. Recommend "freeze" and other orders.
12. Secure the necessary assistance of all Government agencies and the industry in parts of the program.

WPB put together a staff consisting of six men familiar with compressor production and use, with authority to take all necessary steps to effectuate the program. This unit was authorized to act as the sole contact between the manufacturers and the procurement agencies or other customers in expediting the delivery of the compressors.

The indicated requirement for the following twelve months of large compressors, that is, those of 300 horse-power and up, substantially all of which were direct engine-driven, was in the neighborhood of 1,000,000 horse-power, with a similar requirement for the succeeding twelve months. The customers had bulked the deliveries in the fall of 1942. From the data then at hand, it appeared that there was an insoluble problem and that many of the new plants desperately needed would be held up for lack of compressors. Eight months' production was needed in four.

On April 17, 1942, the Board issued Order L100, which became the model for many similar scheduling orders. Prohibited was the placing or acceptance of orders for critical compressors unless specific authorization was made after application to the Board. Manufacturers on whom orders were authorized were required to accept such orders. In addition, regardless of any prior commitment or preference ratings, manufacturers

were to deliver compressors only in accordance with schedules approved by WPB.

Before issuance of the order the principal manufacturers were called together as an industry advisory committee, and assured us their cooperation. As will be seen, the order was drastic in its terms, and required a great amount of paper work on the part of the manufacturer. However, the producers were under terrific pressure from competing claimants, and welcomed any mechanism that would relieve them of the decision as to which compressors should be delivered first.

After receipt of the order boards from the manufacturers, the group began wearing out shoe leather consulting with the procurement agencies on those compressors identified as coming under their jurisdictions, and determined the latest needed date for the equipment. Soon after this crew got to work it became apparent that customers had requested, in general, dates much earlier than the actual needed dates. For example, one plant had ordered delivery of 45,000 horse-power for October, 1942, when an optimistic estimate for the start of operations was late 1943. When the true needed dates had all been secured, things looked better. Freezing of the order boards allowed orderly planning for production, permitting raw materials to be secured in time for needs and allowing work once started to be completed. One of the principal difficulties being encountered was the "leap-frogging" of one order over another by reason of the securing of a better preference rating by the agency interested. Castings and forgings ordered for one set of machines as well as partially completed machines had to be put aside and stored, so that work might begin on later orders that had received higher preference rating. A 25% expansion of facilities was accomplished through the expediting of the tools and the construction needed. Continual pressure on the contractors for subcontracting of parts also speeded production. While it was necessary to continue "hand scheduling" into 1944, the 1942 fall crisis, which was thought would wreck the facilities program, actually never occurred. The situation had appeared so critical in May, 1942, that the Requirements Committee staff recommended that policy level decisions should be made on the basis of the few highly critical materials, and named the following: steel plates, alloy steel, copper, aluminum, rubber and compressors. The crisis, however, evaporated and there is no record of any important plant failing to go into operation because of late arrival of a compressor.

The mechanisms for handling this scheduling may be of interest. A master order board, similar to those used in the old days in jobbing foundries, was built and erected. This board measured some six feet high and twelve feet across, and occupied one wall of the room that housed it. Across the top horizontally it was divided into thirteen spaces, twelve for the months of the year, and one for unscheduled orders. Under each month, also in a horizontal column, appeared the names of the seven principal manufacturers. Vertically along the left-hand side of the board, and again in duplicate along the right-hand side, were titles indicating the size and type of the compressor. We now had twelve monthly divisions

horizontally across the board, seven minor division under each month horizontally, and some twenty compressor types listed vertically. Nails were driven part way into the board in each space---some 1700 in all--- providing the pegs on which to hang tickets. Tickets were typed for all of the compressors shown on the order books of the manufacturers, care being taken that only one type was noted on any ticket. Where more than one month of delivery had been indicated, separate tickets for separate months were made. Different colors of the tickets indicated the type of drive, that is, whether steam, gas or electric. A hole was punched near the top of the ticket to allow it being hung on one of the nails of the board.

This allowed all of the orders to be sorted by month of delivery, manufacturer, type of unit, and kind of drive. When all the tickets had been hung on the 1700 nails, the overloaded and underloaded portions of the board could be seen at a glance. Where any particular spot was overloaded, conferences of the claimants were called and I am glad to say that in every case it was possible to reach agreement after a full hearing. While the major crisis had evaporated, minor crises continued to occur almost daily. Battle damage occasioned considerable diversions, all of which were amicable. The Navy got four needed compressors at Pearl Harbor in thirty days, through diversions with the consent of Army Ordnance. The Boston Navy Yard was able to get a compressor in three weeks to put a damaged escort vessel back to sea by diverting one from a new steel foundry, the completion of which was later than the original expected completion date.

Other such industry-wide "hand-scheduling" included large turbo-blowers, high pressure boilers and heat exchangers. Fortunately, it was not necessary to "hand-schedule" too many complete industries.

Electric Controls

In general, such scheduling of a few companies only in a particular industry solved the problem, usually there being a few leaders who were forced to take orders in excess of their capacity. An example of this was in the field of electric controls---Cutler-Hammer was in trouble in the fall of 1942. "Leap-frogging" and uprating of preference ratings had proceeded to such an extent that substantially everything on their books had been raised to an AA-1 category. They were receiving hundreds of expediting telegrams and phone calls daily; a large staff of expeditors, many in uniform, were at the plant, pressing the management for earlier deliveries. Electric controls are small but important pieces of apparatus---consisting of from one to one hundred items mounted on a panel. Monthly items ran into thousands for a company the size of Cutler-Hammer.

When "hand-scheduling" was first proposed, the size of the problem horrified everyone consulted. However, there appeared no other solution. Every order was accordingly identified with the end-use, whether a particular ship, an industrial facility, or the like. The ship schedules of the Navy, Maritime Commission, and Army shipbuilding units were

secured and kept up to date. Lead times were set for the time of shipment of the control as so many months before the completion date of the ship. Similar schedules were secured for completion dates of the various facilities. The complete order board was then rescheduled in terms of needed dates, allowing ample lead time. Before the orders were rescheduled, required deliveries for the following six months period amounted to 150% of capacity, whereas after rescheduling, such required deliveries had shrunk to only 75% of capacity--and Cutler-Hammer went out for more business. As will be realized, the task of covering some 17,000 items, and 2,700 orders, took considerable time---some ten thousand man-hours---but as events proved, it was well worth the effort. After the initial rescheduling, it was a simple matter properly to schedule new orders, by insisting upon an identification of the order with end-use, and then applying the predetermined lead time to the completion date of the end product.

Welding Rods

Welding rods used in ship construction and in the many industrial plants working on essential programs proved to be a type of problem that did not lend itself to "hand-scheduling". Estimates were made of the monthly consumption of rods, taking into account the shipbuilding programs, construction of industrial facilities, and miscellaneous uses. These early estimates proved to be remarkably accurate, and although the situation was always tight, since it called for a rapid monthly step-up in rod productions up to March, 1944, it is believed that no important project was delayed through lack of rods. Almost daily shipyards on the West Coast engaged in the Maritime program would call the welding rod chief in WPB demanding additional and immediate shipments, saying they were about to shut down for lack of rods. Believing that they were receiving ample rods, based upon manufacturers' shipping reports, and shipbuilding schedules, he sent out investigators to determine the size of inventories. These he found were large and mounting. Accordingly, he determined to outguess the complainers; --- one day, before he had received any calls, he phoned those West Coast yards saying he was stuck with an excess of 1,000,000 pounds, and asking each of them to take this quantity off his hands. (If any had called his bluff he would have been in trouble.) However, he got evasive answers with promises to call back if they could use the rods, and from that day on his calls from the West Coast stopped. This device was used in several other commodities, and often proved effective in stopping panic buying. It will be remembered that when rationing of coffee ended, the demand immediately dropped off. It is human nature to hoard scarce commodities, and to use up the accumulated hoard when the supply appears adequate. In period of expanding production, large demand is occasioned not only by large consumptions, but also by the filling of larger pipe lines and by hoarding. In the case of welding rods, the controls which proved effective required large users to make a monthly request for authorization to buy, identifying the use of the rod with particular programs and schedules, and tabulating inventories on hand. These requests were balanced with the producers' capacity, and shipments scheduled accordingly.

Anti-friction Bearings

Another item that employed a modification of this type of control was anti-friction bearings. It will be remembered that the acute situation hit us early in 1943, and continued for the rest of the war. Here, again, panic buying, and excessive inventories, aggravated the problem. A large increase in plant capacity had been provided during 1942, and it appeared that the industry would be able to take care of the expected demands. However, the material shortages that cropped up in the third and fourth quarters of 1942 resulted in allocations of alloy steel to the bearing manufacturers far below the requirements of the capacity then ready. As a result, operations were curtailed at the very time they should have been increasing, and labor was lost to other war plants then expanding in the Connecticut Valley. The labor shortage in the bearing plants then continued to plague us for the rest of the war. Although strenuous efforts were made by the War Manpower Commission and others, the plants were never able to operate at full capacity. Bearing production did achieve the remarkable figure of over 33,000,000 per month, but it was not until scheduling controls were put into effect that the acute shortages disappeared. As will be realized, in the millions of bearings per month, there were many thousands of orders containing many separate items. However, by screening the applications of large users, by requiring identification with approved end-product schedules, by scrutinizing inventories, and by the excellent cooperation of the services in combining inventories of various bearings, identifying the many different part numbers with particular bearings, the problem eventually was gotten under control.

Machine Tools

Machine tools were early on the list of critical items. Months before Pearl Harbor there was a realization that the tools needed for the military program then on paper, were non-existent. An early appraisal revealed that the programs then considered huge, but later increased many times, for ships, aircraft, tanks and ordnance, would use new and large tools far in excess of anything available, and that time was needed for the building of these tools. The Office of Production Management, the predecessor of WPB, moved in by placing "pool orders" for tools that would be later needed by the prime and sub-contractors. Government funds were made available for such purchases, and it was expected that the Defense Supplies Corporation would pay for and hold the tools until they were needed. However, as events developed, these tools were shipped and paid for by individual contractors as soon as they were finished, and no large inventory of tools was ever accumulated. "Pool orders" was a necessary device in an industry such as tools, since the production cycle was long, and efficient production required sizeable lots of one type. Accordingly, "pool orders" were continued well into 1944, and were discontinued only when the demand for tools had fallen off sharply. Scheduling in this industry was accompanied by assigning 75% to the Army-Navy Munitions Board, which in turn allocated to the Armed Services their various percentages. The balance of the 25% was "hand-scheduled" by the

Board upon the showing of need. The device of frozen order boards and diversions between customers proved to be the forerunner of these controls in many other items. The bulk allocation method with detailed allocation by the claimant was adopted for materials in the Controlled Materials Plan.

Steel

Another type of scheduling was exercised in such widely used commodities as steel. This was the "production directive". The Board informed each producer of steel, quarterly and monthly, as to what he should produce. These production directives stemmed from a study of important programs and the types and sizes of steel needed to accomplish the production objectives. As will be realized, this type of control was an approximate one because of the complexity of the problem, but was the only one possible in an industry with so many ramifications. Parenthetically, it should be said that this was true production scheduling, as distinguished from scheduling of shipments. It will be noted that many of the controls with which this paper deals were concerned with scheduling of shipments, which in turn required the manufacturer to schedule production. However, as generally used during World War II, the term "production scheduling" covered not only the scheduling of production, but also the scheduling of shipments.

The Record and the Lesson

The record shows that production of munitions and construction valued at August, 1945 prices, and stated in billions of dollars per month, was as follows: at the end of 1940, 1/2, 1941, 2; 1942, 5; 1943, reaching a peak of 5-3/4 in November, and leveling off to about 5-1/2 billion dollars per month in 1944. The winning of the production battle in 1943 made possible the landings in France in 1944 and victory on all fronts in 1945.

I was privileged to see at first hand in Europe for some six months before V-E day the flow of material to our fighting forces. The supply proved adequate and flowed over a veritable bridge of ships and a river of trucks. No enemy could long survive that avalanche of steel.

It is realized that the next war may be a very different one from the last. New weapons will change the emphasis on types of production. It may well be that the volume required may be much less or greater. The preparation for production will necessarily be geared to strategic planning, but once the requirements for ships, aircraft, tanks and ordnance are determined, it is possible to total the requirements of materials and components. It is indicated that a high-level group be in existence, which would include in addition to representatives of the Armed Services, persons cognizant with other essential requirements, who would study and determine the allocation of the total potential supply of materials, components, facilities and manpower.

In World War II, general scheduling of products and materials-- that is the balancing of supply and demand--evolved by trial and error a year after Pearl Harbor, and another year passed before production reached its peak. Many lives were lost by the delay. Possibly the next time the interval between our being attacked and our being ready, if it is again so long, may well prove fatal. We have had experience--let us profit by it.

CAPTAIN WORTHINGTON:

We are now open to questions.

A STUDENT:

In our committee we frequently run into the two terms "program scheduling" and "production scheduling." Up to date I have gotten as many different definitions of them as the people I have talked to. I wonder if you would add to my perplexity by giving me your definition.

MR. FRANK:

"Program scheduling" was a term used in the Controlled Materials Plan. It required the Claimant Agencies to schedule programs of end products, and to translate these programs into quantities of controlled materials by calendar quarters. Production scheduling was done at the manufacturer's level, and scheduled the production or more usually the shipments of the particular manufacturer.

A STUDENT:

How far could the military go in establishing priorities? Where could the WPB step in to avoid interference with its production program? There has to be some balance there. You mentioned your control of components that was made by WPB, and said that it had to be done in order to get out the adequate volume. But then, of course, our military program must be established by the operating forces. How far should that go?

MR. FRANK:

That was a moot point early in the war. It got pretty well settled as we went along.

It was quite apparent, as long as we had a large amount of non-essential production in the civilian economy, that under a priority system the military could take those things that were non-essential in the civilian economy. However, as the military program expanded, it became evident that even if this program took everything, there would still not be enough to meet the program. The military program was

larger in 1942 than the whole production of materials could support even if we gave nothing to the civilian economy.

It became evident then that there had to be allocation, and that some of the materials had to be allocated to the essential parts of the civilian economy. The railroads had to keep going. The farmers had to have some farm equipment in order to produce food in large volume, and there were many other essential needs that had to be taken care of. As the controls evolved WPB allocated all materials which were essential to production.

In the matter of components, take a thing like electric motors. Electric motors went into ships, tanks, and aircraft, all kinds of Ordnance equipment, and to many new industrial plants that were making the military items. The military could not in the nature of things allocate motors to all users. They could only indicate their own requirements.

WPB then reconciled essential requirements with supply and allocated the supply among the claimants. Production scheduling was similarly a method of allocation where demand exceeded supply-either of one manufacturer or of a group of manufacturers.

A STUDENT:

Do you think it would be possible or feasible to construct and use fiscal control, that is, a limit on the amount of money available, of the armament program, including Lend-Lease, so as to limit it to that portion of the national production as would be available for that purpose?

MR. FRANK:

The dollars would control the total volume but would not control the type of production. It was necessary to have a detailed control of "bottle-neck" items. Some programs used steel, some used copper, and some used aluminum. The original limitation on the aircraft production was aluminum sheet. Programs are limited by the supply of critical items, either materials or components. The dollar control is too broad. You need a continuous study of the critical items to determine how large can be the totals of programs using those items.

CAPTAIN WORTHINGTON:

Thank you very much, Mr. Frank, for a very valuable talk.

(19 Feb. 1947---350)E