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CHAPTER X

THE EFFECTS OF MECHANIZATION

IN APPRAISING the effects of mechanization it must be kept in mind that we are not here considering contrasts between modern mechanized methods and handicraft methods of earlier centuries or in distant and undeveloped countries. We are asking, rather, what are the effects of further mechanization here and now in industries most of which are already in a relatively advanced stage of mechanization.

Our primary concern in this study is with the effects upon the quantity of labor required in industrial processes. It is pertinent, however, to inquire also into the other effects of mechanization, for these other effects, aside from their general industrial and social significance, are important factors in determining the rapidity with which mechanized processes are introduced. To cite one example: to the extent that spray-gun painting is believed to be harmful to the worker, it involves expense for protective devices and may arouse legislative or union action to curtail its use. To the extent that it is believed to save material or result in a better job of painting, its use is encouraged. Similar examples could be multiplied indefinitely.

EFFECTS UPON THE QUANTITY OF LABOR

In analyzing the effect of labor-saving changes upon the quantity of labor required, the major questions, in order of their consideration in this chapter, are: (1) What are the typical reductions in crew arising from various devices mentioned in previous chapters? (2) Can the total labor-saving effect of some be estimated, either for the aggregate number of total installations already made, or even of the possible total effect if more or less completely introduced in the sphere of work for which they are adapted? (3) What may we learn by summarizing the labor-saving changes reported to us by factory executives? Do these suggest that the typical change affects many or few men? And is there ordinarily a marked difference between labor-saving effects when we measure only the actual reductions in crew or when we also allow for any increase in the total output of the crew? (4) Turning to the more comprehensive statistics of employment and occupations, what estimates have been made of the total effect of all sorts of technical improvements in the decade of the 'twenties—what estimates, in other words, as to how much of the total change in employment can be ascribed to improvements in productivity, whatever the cause, and how much to changes in the total volume of output? (5) Passing to the more human side of the problem, is there reason to believe that the increasing use of machines not only reduces the amount of labor required for a given volume of production but also that it causes at least temporary unemployment of the individual worker? What evidence upon this question of technological unemployment is afforded by the several studies that have been made of employment histories of individual workers, or of the unemployment in the total membership of given trades or occupations? Does the available evidence suggest that the typical effect of technological improvements is at least a temporary increase in the volume of unemployment? (6) Are the arguments and evidence for the alleged tendency of the machine to create a permanent increase in the volume of unemployment adequate and convincing?

Not all of these questions were subjects of direct inquiry in the field phase of our survey. We did not attempt, for example, to trace the subsequent employment histories of the men displaced by changes in the factories inspected. Nor is the evidence from any source adequate for a convincing answer to some of these questions. It is pertinent to our problem, however, to indicate the nature and purport of such evidence as is available.

SELECTED MACHINES

An attempt at anything approaching a complete enumeration of labor-saving improvements is impracticable and unnecessary. A relatively small number of illustrations must suffice. The reductions stated are in most instances only in the crew on the specified operation, not for the total labor force of the plant (unless so designated), and refer to the effect upon the labor directly required, with no allowance for indirect effects such as a possible increase in repair or supervisory labor.[1] The citations in parentheses are to the numbered references in Appendix D.

In agriculture, the harvester-thresher combine is estimated to reduce the labor required for harvesting and threshing wheat 84 per cent as compared with the use of binders and stationary threshers; and 80 per cent as compared with the use of headers and stationary threshers.[2] In the mining of bituminous coal, mechanical loading devices are estimated to reduce the labor in loading some 25 to 50 per cent.[3] A similar reduction was accomplished in

[1] *Cf.* discussion, in Ch. II, of 'productivity', 'labor displacement' and the 'labor-saving ratio'. For additional examples of reductions in labor required, see Ref. 61.

[2] R. A. Reynoldson, *et al., The Combined Harvester Thresher in the Great Plains,* U. S. Department of Agriculture, Technical Bulletin No. 70 (1928), p. 23.

[3] Ref. 2, p. 35. For 4 mines with fully mechanized loading, the Bureau of

the labor required to deliver materials to the paver in highway construction when central proportioning plants replaced the roadside dump and wheelbarrow proportioning method.[4] The finishing machine for cement highways is estimated to save from 2 to 7 men, or 40 to 60 per cent of the labor on finishing. In the painting of buildings, where the paint-spray gun can be used, it is credited with a capacity to reduce the labor required from 80 to 85 per cent (Haber, Ref. 13, p. 43). In the field of commercial amusements, the introduction of the 'talkie' with synchronized musical score reduced the employment of musicians in the moving picture theaters about 50 per cent (Ch. IV, and Ref. 44 and 46).

Passing to the handling phase of the manufacturing industries, we find that the electric storage battery trucks introduced by our informants eliminated on the average about 3 men per machine. Savings by other types of handling equipment are also very important but cannot be as readily reduced to significant statements of average effects.

For the processing operations in manufacturing, numerous examples may be cited. In two factories reporting to us labor savings by the introduction of the cigar machine, the reduction was 50 to 60 per cent.[5] In window glass manufacture, the cylinder machine reduced the labor cost in dollars about 57 per cent for single-strength glass and about 42 for double-strength; the Fourcault sheet machine, about 62 per cent for single and 56 for double (B.L.S., Ref. 36, p. 159). In the glass bottle industry, the semiautomatic machine, compared with the most efficient hand process,

Labor Statistics found the reduction in labor required to be nearly 40 per cent when mechanical loading methods were introduced (Ref. 63, pp. 267–8).

[4] From information obtained by us from users of the given method or machine.

[5] About the same labor reduction ratio is ascribed to the cigar machine by Mary Anderson, Director, Women's Bureau, U. S. Department of Labor, in When Machines Make Cigars, *American Federationist*, 1932, pp. 1375–81.

accomplished a reduction of from 29 to 71 per cent, and the automatic machine from 86 to 97 (B.L.S., Ref. 36, pp. 49–54). For the pressed-ware branch, the most efficient machine for various selected types effects a reduction of from 80 to 92 per cent; in the blown-ware branch, of from 30 to 97 (B.L.S., Ref. 36, p. 7). In the foundry industry, the instances coming to our attention indicated a saving of from 3 to 4 men by the installations of sand-cutting and mixing equipment, and of from 4 to 5 men by molding machines of the roll-over and sand-slinging type. In cotton cloth manufacture, the automatic looms seem to require a crew about two-thirds as large as that needed for non-automatic.[6] The warp-tying machine was credited by our informants with a reduction of from 10 to 15 workers per machine; the drawing-in machine with from 3 to 5. The high speed spooler and warper combination apparently saves about 50 to 55 per cent of the labor required in the warping operation (Ch. III). In the commercial printing industry, Dr. Baker found that "the automatic feeder accelerates the speed of printing some 20 per cent—to 1,200 to 1,300 impressions per hour as compared with some 1,000 by hand" (Baker, Ref. 5, p. 447). In the small group of establishments in the clothing industry surveyed by us, machines reduced the labor involved in pressing by from 50 to 60 per cent. In his survey of a group of representative automobile tire plants, Boris Stern found that the change from regular mixing mills to Banbury mixers reduced labor requirements in the mixing and compounding divisions about one-half; and in tube manufacture, "the man-hour output of the watchcase method is over four times that of the pot heaters", nevertheless, the transition to the watch-

[6] Based upon a comparison of the looms per weaver in 5 non-automatic and 8 automatic-loom mills producing substantially similar types of cloth.

case system has been very slow because of the expense of scrapping the old equipment.[7]

In compiling the above illustrations we have selected equipment changes of substantial labor-saving significance but have tried to avoid exceptional and spectacular instances which are likely to create an exaggerated impression of the actual or potential labor saving. In this way we hope to make the estimates fairly representative of what may be expected in the ordinary run of installations. Even so, these estimates should not be interpreted as purporting to have the precision essential as a guide, for example, to the wheat grower who is considering whether to purchase a combine, or the manufacturer who is weighing the relative advantages of hand-power and electric trucks for indoor haulage. Such decisions require intimate knowledge of the special conditions pertaining to the particular establishment. What we have endeavored to give are the best possible estimates of average tendencies—estimates which may be used for reasonably accurate approximations of the probable effects of a relatively widespread adoption of the given device.

Total installations[8]

We have just cited examples of the approximate typical reduction in labor ascribable to selected types of labor-saving machines. Many of these types do not lend themselves to an estimate of their total effect, but some suggestion of the aggregate influence may be afforded by estimates for a selected few. Taking the number of units installed by the

[7] U. S. Bureau of Labor Statistics, Bul. 585, *Labor Productivity in the Automobile Tire Industry*, 1933, pp. 41, 60.

[8] For estimates of constructive displacement in various industries arising from the combined effect of all changes affecting productivity see subsequent section, Aggregate Constructive Displacement.

specified date, and multiplying this number by the approximate average number of men displaced per unit, we reach estimates that the 12,000 electric trucks in use in June 1928 represent the constructive displacement of about 36,000 men; the cigar-making machines installed by the close of 1929, 16,800 workers, the 900 warp-tying machines, 10,800, and the 140 sandslinging machines about 700.[9]

These estimates are, of course, for constructive rather than actual displacement. That is, if the industry has expanded, they merely represent jobs that might otherwise have been filled by additions to the number of manual workers. If the industry has not expanded in total output, they presumably indicate an actual reduction in the number of workers employed on the operations upon which the machine is used.

Potential further displacement

In the immediately preceding paragraphs, we have presented estimates of the constructive man-power displacement of the aggregate installations of various machines.

[9] In view of the fact that the discussion of the labor-saving qualities of selected machines in the immediately preceding paragraphs, and of total installations in this section, runs in terms of the reductions in operating workers on the immediate processes affected, it may well be reiterated at this point that labor saving in one process may increase the demand for other kinds of labor—in the making of machines and their repair and maintenance, and in still more indirect ways. See, for example, the distinctions in Ch. II between 'operating, auxiliary, embodied, and indirectly required labor'. These indirect effects give rise to differences in the appraisal of the result of a given change according to whether the unit considered is merely the single process, the plant as a whole, manufacturing industry as a whole (including the production of the machine), or even the entire industrial process from the acquisition of the raw material to the placing of the finished goods in the hands of the consumer. See Ch. VI for discussion of the labor involved in the production of machines.

Estimates of potential additional displacement are much more difficult. However, one or two tentative approximations may be of interest as suggesting a type of estimate that may become of increasing usefulness as our knowledge of industrial organization, occupational distribution and mechanization procedure becomes more adequate as a basis for the appraisal of future developments.

A combination of machines known as the 'automatic spooler and high speed warper' has been introduced in some cotton mills as a substitute for older and slower types of machine for the warping and spooling processes. About 7 per cent of the labor force in the cotton mills included in our survey were engaged in these processes. The labor reduction attributable to the new machine we estimate to be about 50 per cent (see Ch. III). If we assume that in about one-fifth of the mills these machines have already been introduced or cannot be used to advantage, we reach an estimate that a general introduction of the 'automatic spooler and high speed warper' would accomplish a further labor reduction of about 2.8 per cent of the total mill force, or some 12,500 workers for the industry as a whole.

This illustration is relatively unimportant in itself but it serves to call attention to the type of information needed as a basis for a reasonable approximation of the labor displacement to be expected upon general adoption of a new machine—the number of persons in the occupation affected, the reduction ratio attributable to the machine, and the percentage of plants in which the use of the machine is feasible.

LABOR REDUCTIONS IN THE PLANTS SURVEYED

Summaries of the labor-saving changes reported to us are presented in Tables 34 and 35. In Table 34, the classification is by number of men saved per plant; in Table 35 by the number of men saved per reported change. In each table the data are presented on two bases, the second giving a constructive rather than an actual displacement.

In popular discussion of labor saving, attention is apt to be centered only on the spectacular instances of large reductions. These are, of course, important, but it is also noteworthy that in nearly two-thirds of the 356 instances of labor saving tabulated in Table 35, the crew reductions were less than 10 men.[10] Even on the plant basis (Table 34) it is still true that over half of the reported changes effected reductions of less than 10 men. It would appear that a substantial part of the total reductions of labor requirements in an industry takes place by this gradual process of nibbling away at the size of the staff required.[11]

Substantial differences between the results derived on Basis A and on Basis B will be noted. The total number of men reported as 'saved' by the 356 labor-saving changes is 5,572 if no allowance is made for increased output but rises

10 The importance of relatively small but numerous changes in method is stressed by Boris Stern, who has devoted several years to the conduct of productivity studies for the Bureau of Labor Statistics (see *American Statistical Association Journal,* March 1933, *Supplement,* p. 42). In the electric lamp industry, for example, the minor changes are probably more important in the aggregate than the relatively few major changes (Ref. 65, p. 1216). Even in the tire industry, while there have been some revolutionary changes, notably the introduction of the flat-drum process in 1926, "the increased productivity of labor was due more to the so-called evolutionary small changes in production than to any revolutionary change in the process of tire manufacturing" (Ref. 62, p. 1264).

11 The number of men saved and the total labor force in the reporting plants could be compared but we do not believe this comparison should be stressed too much, for certainly in some plants not all the labor-saving changes actually made were reported. In Group I the reported savings were equal to 4.6 per cent of the total labor force if no allowance is made for increased output, or 5.1 with such allowance. The corresponding percentages for Group II are 3.0 and 8.6 respectively.

TABLE 34

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN SAVED PER PLANT[1]

All changes reported for a single plant combined and counted as one change
Basis A: no allowance made for increase in total output of crew

NUMBER OF MEN SAVED	NUMBER OF CASES: ALL GROUPS	NUMBER OF CASES: GROUP I	NUMBER OF CASES: GROUP II	TOTAL NUMBER OF MEN SAVED: ALL GROUPS	TOTAL NUMBER OF MEN SAVED: GROUP I	TOTAL NUMBER OF MEN SAVED: GROUP II
Total, all plants	246	177	69	5574	4117	1457
Under 10 men	132	93	39	498	365	133
10 to 19 men	50	41	9	686	568	118
20 to 49 men	40	29	11	1135	842	293
50 to 99 men	15	8	7	916	485	431
100 or more men	9	6	3	2339	1857	482

[1] See footnotes to Table 35 for sources of data in this table.

to approximately 8,633 if such allowance is made. The former figure represents the immediate impact of the changes on the crews; the latter figure gives a more complete indication of the probable effects on labor requirements in the industries as a whole. One plant may introduce a labor-saving device, but, by capturing a larger share of the market and increasing its total output, may avoid reducing the crew; obviously, however, this cannot be done in all plants in the industry unless there is an increase in the total market for the given product.

AGGREGATE CONSTRUCTIVE DISPLACEMENT IN SELECTED INDUSTRIES

We have cited examples of the labor saving per unit for various machines, and for some, estimated the labor displacement attributable to the aggregate installations made; also, we have noted the extent of labor-saving changes re-

TABLE 34 *(cont.)*

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN SAVED PER PLANT

All changes reported for a single plant combined and counted as one change
Basis B: allowance made for increase in total output of crew

NUMBER OF CASES			TOTAL NUMBER OF MEN SAVED			
ALL GROUPS	GROUP I	GROUP II	ALL GROUPS	GROUP I	GROUP II	NUMBER OF MEN SAVED
246	177	69	8625	4363	4262	Total, all plants
123	92	31	500	370	130	Under 10 men
49	39	10	661	539	122	10 to 19 men
43	30	13	1286	889	397	20 to 49 men
16	9	7	1015	541	474	50 to 99 men
15	7	8	5163	2024	3139	100 or more men

ported by the establishments included in our survey; but it is obvious that because of the diversity in form and effect of labor-saving changes, not to mention the lack of detailed information for a great many types, it is impossible to build up from the estimates of the effect of individual types of machine anything approaching a close estimate of the aggregate effects of the totality of labor-saving changes in any given period. We must resort to an analysis of the data for total employment and total output by industries in order to secure a rough approximation of the joint effect of the aggregate of forces which in the post-War period have been brought to bear upon the industrial utilization of human labor.

Estimates of constructive displacement will vary according to whether we make comparisons on a fixed base year or from year to year, and also whether we estimate the displacement by applying the differential between current and base-year productivity rates to the current-year output or to

TABLE 35

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN SAVED PER INDIVIDUAL CHANGE[1]

Basis A: no allowance made for increase in total output of crew

NUMBER OF MEN SAVED	NUMBER OF CASES: ALL GROUPS	NUMBER OF CASES: GROUP I[2]	NUMBER OF CASES: GROUP II[2]	TOTAL NUMBER OF MEN SAVED: ALL GROUPS	TOTAL NUMBER OF MEN SAVED: GROUP I	TOTAL NUMBER OF MEN SAVED: GROUP II
Total, all cases	356	287	69	5572	4115	1457
Under 10 men	219	180	39	928	795	133
10 to 19 men	75	66	9	1031	913	118
20 to 49 men	40	29	11	1172	879	293
50 to 99 men	13	6	7	807	376	431
100 or more men	9	6	3	1634	1152	482

[1] If a plant reported more than one labor-saving change, the changes have not been combined but are treated as separate instances. Part A represents the results in the way of reduction in the size of crew, when no allowance is made for change in the crew output. Part B represents the difference between the crew at the time of reporting and the crew that would have been required under the former method to equal the output of the actual crew under the new method.

the base-year output. Combinations of these alternatives give us four basic methods of estimate:[12]

[12] We may state these four methods algebraically thus:

Method A: $T = P_1 (L_1 - L_0)$
Method B: $T = P_0 (L_1 - L_0)$
Method C: $T = \Sigma[P_1 (L_1 - L_0)]$
Method D: $T = \Sigma[P_0 (L_1 - L_0)]$

Where,

T = the constructive technological change in the volume of employment (expressed in number of workers or man-years, man-weeks, man-days, or man-hours, as the case may be).

P_1 = total output in physical units in the current year; P_0, in the base year.

L_1 = the labor requirement ratio in the current year (labor per unit of output); L_0, in the base year.

TABLE 35 (*cont.*)

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN SAVED PER INDIVIDUAL CHANGE

Basis B: allowance made for increase in total output of crew

NUMBER OF CASES			TOTAL NUMBER OF MEN SAVED			
ALL GROUPS	GROUP I	GROUP II	ALL GROUPS	GROUP I	GROUP II	NUMBER OF MEN SAVED
356	287	69	8633	4371	4262	Total, all cases
210	179	31	936	806	130	Under 10 men
73	63	10	990	868	122	10 to 19 men
46	33	13	1566	1169	397	20 to 49 men
13	6	7	850	376	474	50 to 99 men
14	6	8	4291	1152	3139	100 or more men

[2] Group I represents chiefly inspections (with a few mail inquiries) made in the summer of 1925. Group II represents replies to an inquiry made by mail in 1928. In Group I an effort was made to obtain all labor-saving changes. In Group II, only "the single change made since 1920 which resulted in the greatest saving of labor" was asked for.

Method A, the fixed-base, current-year-output method,

answers the question: How much less labor did it require to produce the current output than would be required at the productivity rate of the base year?

Method B, the fixed-base, base-year-output method,

answers the question: How much less labor would be required to produce the base-year output at the current productivity rate than actually was required at the base-year productivity rate?

Method C, the year-to-year, current-year-output method,

answers the question: What is the cumulative constructive displacement when the displacement for each year is computed by multiplying the current year output by the differential between the labor requirement ratios of the current and the immediately preceding year?

Method D, the year-to-year, preceding-year-output method, answers the question: What is the cumulative constructive displacement when the displacement for each year is computed by multiplying the output of the preceding year by the differential between the labor requirement ratios of the current and the immediately preceding year?

A simple hypothetical example may help to make clearer the differences in these four methods. Assume that in 1927 an industry employing on the average 100 workers had an output of 1,000 units and hence a labor requirement ratio of 0.1 worker per unit. The corresponding data for 1928 are 100 workers, 2,000 units of output, and a labor-requirement ratio of 0.05 workers per unit; and for 1929, 150 workers, 6,000 units of output and a labor-requirement ratio of 0.025 workers per unit.

Under the conditions assumed, the constructive labor displacement in 1929 is 450 if the differential in 1927 and 1929 in the labor-requirement ratios is applied to the 1929 output (Method A), but only 75 if it is applied to the 1927 output (Method B). But if the year-to-year method is applied by first estimating the displacement from 1927 to 1928, and then from 1928 to 1929, and cumulating the two results, the displacement is 250 if the labor-requirement differential is applied to the current year output in each instance (Method C), but only 100 if it is applied to the preceding year output (Method D).

If there have been changes in the length of the working week or working day in the period covered, their effect is included with the other forces determining the labor-requirement ratio.

Which of these four methods is most logical? Ordinarily the year-to-year method is preferable and nearer to reality than comparisons with a distant base. In the first place, the year-to-year changes in employment due to technological improvements are probably more important than the relatively long-time or possibly permanent displacement effects.[13] Furthermore, the significance of estimates of the constructive displacement of labor is obscured by any degree of interdependence between changes in total output and in productivity rates. If total output and productivity are independent of each other over a long period, then the fixed-base method may be reasonably accurate; but if, as is more often true, the trend in the total output of the industry is in part both effect and cause of changes in the rate of productivity, then of the two methods, the comparisons with the preceding year as a base are the less likely to be distorted by the interdependence of changes in total output and in productivity rates.[14]

Also, when using the year-to-year method the arguments for applying the labor-requirement differential to the output of the current year are in most instances more cogent than those for applying it to the preceding year output. As suggested by the Bureau of Labor Statistics, "in the larger industries, such as the electric-lamp industry, the volume of production in any given year is determined primarily, not by any decrease in labor cost during the year, but by the actual or estimated demand for the product".[15]

When we turn to the available estimates of constructive

[13] *Cf.* discussion of the Volume of Permanent Unemployment in a subsequent paragraph.

[14] *Cf.* B. L. S., Bul. 585, p. 15.

[15] Ref. 65, p. 1220.

displacement in the several industries we find no one of these methods used exclusively, although resort is had most frequently to Method A, that is, to estimates of the greater amount of labor that would be required to produce the current output at the productivity rate of some one earlier year.

Thus it is estimated that in 1929, 16,797 more workers would have been required in the cigar industry if the machine output of that year had been made by hand.[16] In the Bell telephone system, because of expanding volume of business, the number of operators actually increased from 118,470 in 1921 to 143,979 in 1930 despite the increase in the number of stations served by dial telephones; but it is estimated that 69,421 additional operators would have been required to handle the 1930 volume of business at the 1921 output-per-operator rate.[17] The volume of business handled in 1931 by 8,460 operators with the printer telegraph in 'functional' offices of the commercial branch of the telegraph industry would have required 16,926 Morse manual operators or approximately twice as many.[18] Likewise, it is estimated that the work of the printer operators in the principal news agencies in 1931 was equivalent to only 243 full-time positions, and that to operate these and the 2,317 receiving positions which they serve, with a complete Morse manual system, would require 3,737 Morse operators.[19] The number of employment opportunities lost, 1924–1929, because of the installation of automatic signals on grade crossings is estimated at 39,258, and the constructive displacement ascribable to grade separations at 2,631 workers.[20]

16 B. L. S., Ref. 47, p. 1277.
17 B. L. S., Ref. 50, p. 243.
18 B. L. S., Ref. 51, p. 510.
19 B. L. S., Ref. 52.
20 B. L. S., Ref. 53, p. 766.

All the above estimates are obtained by applying the differential in labor requirements to the current output, and are expressly or by implication comparisons on a fixed base. Estimates for the postal service and agriculture illustrate the second method of estimate—computations of the constructive reduction in the labor required to produce the base-year output if current productivity rates are applied. By 1929 the efficiency of the postal service had increased so much since 1908 that the output of that year (1908) could have been handled with 193,093 less full-time workers, or a loss of 41.5 per cent.[21] The Bureau of Labor Statistics estimates a constructive technological labor displacement in agriculture of 2,530,000 workers, 1919–27, offset by sufficient increase in the total output so that the actual decline was only about 800,000.[22]

In electric-lamp assembly plants, the total reduction in full-time workers ascribable to improvements in productivity, 1920–29, is estimated as 22,931 by direct comparison between the two years, 1920 and 1929, but only 14,787 if computed on the year-to-year basis.[23]

The application of all four methods of estimating constructive displacement may be illustrated with the aid of data in the above-mentioned study of the tire industry by Boris Stern. The statistics cover output and man-hours, 1922–31, in six representative plants producing from 45 to 60 per cent of the total output of pneumatic tires in this country in those years. Direct comparisons between 1922 and 1929 indicate a constructive displacement of 35,888 workers if the labor-requirement differential between these two years is applied to the 1929 output, but only 13,215 if applied to the 1922 output. If constructive displacement is

21 B. L. S., Ref. 59, p. 759.
22 B. L. S., Ref. 45, pp. 778–9.
23 B. L. S., Ref. 65, p. 1219.

computed for each year in comparison with the preceding year, and the results cumulated for the years 1922–29, we reach an estimate of 23,826 men displaced if the differential in productivity is applied to the current-year output in each instance, but only 20,684 if it is applied to the previous year output. The divergence in the results obtained by the four methods is substantial for an industry like the manufacture of tires which has been changing rapidly in total volume and output per worker or man-hour.

For manufacturing as a whole David Weintraub estimates that in the period 1920–29, 32 men out of each 100 required in 1920 were made unnecessary by increases in output per man, but of that number increases in the total output absorbed 27 (Ref. 23). Using the year-to-year method and summating for the period 1920–29, his estimates indicate that improvements in efficiency in this period had displaced 2,832,000 men or 416,000 more than had been reabsorbed into manufacturing by shortening the working week and increases in total output. Likewise for Class I steam railroads, 1920–29, Weintraub estimates, using the year-to-year method, that 345,000 workers "were displaced by increased technological and managerial efficiency". The corresponding technological displacement in the bituminous and anthracite industries he places at 95,000. For all four of these major industries—manufacturing, Class I railroads, bituminous and anthracite coal mining—Weintraub estimates a decline, 1920–29, arising from changes in productivity, of 3,272,000; meanwhile, 2,269,000 more men were required to handle the increases in the physical volume of output, leaving a net decline in employment in these industries of 1,003,000.[24]

These estimates afford a striking illustration of the wide-

[24] The effects of shortening the working week are lumped with the effects of factors increasing the productivity per hour, but the decline in the length of the working week was relatively small in the years 1920–29.

spread effect of improvements in efficiency in the 'twenties. However, to avoid a possible misinterpretation of their significance it must be noted that they tell us nothing about what part of the constructive gains ascribed to changes in productivity arise from (a) new equipment, (b) chemical and other non-mechanical changes in processing, (c) the elimination of inefficient plants, personnel economies facilitated by mergers or by better organization and management in any respect, (d) improvements in the skill or energy of the workers.

Estimates of constructive displacement, or even estimates of the actual net change in employment resulting from the combined effects of technological change and expansion or contraction in specified industries, do not indicate whether the identical workers who were made unnecessary by gains in efficiency are those who have been absorbed by increases in output. Furthermore, they do not explain to what extent changes in employment have absorbed the increases in population of working age. Nor do they tell us to what extent and how quickly the net losses in manufacturing, railroading and mining have been offset by the expansion of other occupations such as the distribution and service industries.

CONDITIONS FAVORABLE TO A LAG IN ABSORPTION

There is, in fact, considerable evidence to indicate a substantial lag in the absorption by industry of workers displaced by improvements in technique.

Weintraub estimates for manufacturing that during the period 1920–29 "the process of absorption, when not impeded by cyclical recession, lasted approximately one and one-half years". Furthermore, the absorption here mentioned is of the same number of workers, not necessarily the same workers.

Moreover, Dr. F. C. Mills calls attention to the significant circumstance that the figures for aggregate employment in manufacturing, for example, conceal the fact that some industries may be employing fewer men while others are employing more. Hence the total separations in a period may be much greater than the change in total employment suggests.[25] If the average number employed in an individual industry between two census dates is 100,000 and declines 25,000 between these dates, this industry has net separations of 25,000, or a separation rate of 25 per cent. Comparing such separation rates for identical individual industries in the three five-year census periods from 1899 to 1914 and the three post-War census periods from 1923 to 1929, Dr. Mills finds that

> the average separation rate was 4.9 per cent between 1923 and 1929. During each two-year period, on the average, between 1923 and 1929, 49 men out of every thousand employees withdrew or were forced out of the industry in which they were working, as compared with 21 men out of every thousand during a five-year pre-War period (p. 422).

These industrial separation rates measure the minimum demands placed upon manufacturing employees for finding employment in other industries. True, some of these separations are from death or voluntary resignation but it must be remembered that the separations are given as net. An industry may have 100,000 employees at the beginning of a period and 100,000 at the end and yet have forced 20,000 men out and taken in another 20,000.[26] Furthermore, these census statistics give no indication of how much shifting takes place between factories in the same industry.

25 *Economic Tendencies,* pp. 419–23.

26 Each year, in addition to new immigrants, young men and women by the hundreds of thousands come of working age and are available for positions in industry. Also, it is well known that often an older workman is replaced by a younger one. Such replacements would not appear in the total of separations as computed by Dr. Mills from the census statistics.

To assume that the actual mobility between plants and industries is sufficient to make possible the degree of shifting that is known to occur without creating at least some temporary technological unemployment is not reasonable in view of what is known concerning the crudity of the industrial mechanism for facilitating mobility and the personal factors which militate against prompt and perfect adjustment.

DIRECT EVIDENCE OF TECHNOLOGICAL UNEMPLOYMENT

It is regrettable, from the point of view of our present inquiry, that a census of unemployment was not taken near the peak of industrial expansion in the late 'twenties. By the time of the census taking in April 1930, the depression was in progress and the 'technological' element in unemployment, difficult to isolate at best, was still further concealed by the cyclical decline.[27] Of the total number of persons reporting gainful occupations in 1930, 5 per cent or 2,429,062 workers were "out of a job, able to work and looking for a job" on the day preceding the enumeration. In addition to this 'Class A' unemployment, 758,585 or 1.6 per cent of the gainful workers were "persons having jobs but on lay-off without pay, excluding those sick or voluntarily idle".

It would seem reasonable to assume that most of the unemployment that could be ascribed directly to changes in technique would appear as part of the 'Class A' type unemployment. Inquiries were made concerning the reason for being out of a job or for losing the last job held; but only 4.2 per cent of 'Class A' and 1.5 of 'Class B' (or 113,573 in all) gave reasons which fell in the category of 'industrial

[27] Dr. Baker suggests 'technocultural unemployment' as a more adequate phrase than 'technological unemployment' (Ref. 4, p. viii).

policy'. One of the causes included under this caption was 'machines introduced or replaced'. These figures doubtless fall short of an adequate indication of unemployment arising from 'industrial policy'. In the first place, over a third gave immediate or superficial reasons, such as 'no work'. Furthermore, the released worker is often not in a position to know just what caused his release.

More tangible evidence is afforded by various studies of the subsequent history of displaced men by R. J. Myers, Isador Lubin, and Ewan Clague and R. J. Couper.[28] These studies reveal the difficulties of prompt adjustment and support the argument that technological changes frequently create at least temporary unemployment of sufficient length to create a serious problem.[29]

Furthermore, while some of the displaced men included in these three studies obtained employment at higher rates than in their former trades, a large proportion had to accept lower wages in their new employment.[30] Further evidence of actual experience in technological unemployment is afforded by Dr. Baker's study of the commercial printing industry and the experience of musicians after the introduction of the sound movie as reported by the Bureau of Labor Statistics.[31]

In brief, the evidence at hand would seem to indicate a

[28] Myers, Ref. 18; Lubin, Ref. 16; Clague and Couper, Ref. 9.

[29] The phenomenon of 'technological' unemployment is not new. Its actual or threatened existence has been decried ever since the industrial revolution began. It was mentioned, for example, in the United States Census of 1900. The situation in recent years is unique only in that the changes seem to have been more rapid than usual; and, fortunately, there appears to be a greater public consciousness of the existence and significance of the evil.

[30] Lubin ascertained that 46 per cent of the displaced workers earned at least as much on their new jobs as on their old; Myers, about 54 per cent; Clague and Couper, an even smaller proportion, especially of women.

[31] Baker, Ref. 4; B. L. S., Ref. 44 and 46.

tendency for technological changes to result in a substantial period of unemployment for the men displaced and frequently to necessitate their taking employment at a lowered wage. The difficulty of adjustment without loss probably varies, other things being equal, directly with the rapidity with which the innovation is adopted and with the height of the skill differential of the persons displaced.

On the other hand, it has been suggested that the burden of efficiency gains has fallen in large part upon the less efficient worker; that the employer has learned the importance of maintaining a stable well-paid efficient force, and hence when improvements have made reductions in his force possible, he has let go the less efficient workers and it has become increasingly difficult for them to find remunerative occupations.[32]

VOLUME OF PERMANENT UNEMPLOYMENT

In general, the writer does not find convincing the evidence or theoretical arguments sometimes advanced to demonstrate an inherent tendency for mechanization to create an ever larger permanent body of unemployed. We know that, offsetting the check to expansion in certain industries like manufacturing and steam railroad transportation, there has been a substantial expansion of employment in other occupations, such as the distribution and service industries, and the successive censuses of occupations do not furnish evidence of a significant decline in the proportion of the total population reporting gainful occupations.[33]

[32] See Margaret H. Hogg, *The Incidence of Work Shortage* (Russell Sage Foundation, 1932), pp. 26–30, for relation between age and unemployment in New Haven: "the rate of idleness from lack of work for men appears to increase at a nearly uniform rate from the late 'thirties onward."

[33] See an analysis of this point by Dr. W. I. King, Ref. 15; also see Ch.

The element of truth in this charge against the machine lies in the fact that there is a lag in absorption; and consequently the more rapid the displacement, the greater, probably, is the pool of at least temporarily unemployed workers. It may be a pool made up of ever changing individuals but even at that it represents in a sense a more or less permanent addition to the volume of unemployment.

Furthermore, it is quite possible that increasing mechanization has some bearing upon the magnitude of elements in unemployment other than the 'technological' factor. Let us consider, then, the relation between mechanization and regularity of operations.

EFFECT ON CYCLICAL IRREGULARITY OF OPERATIONS

Some students of the business cycle trace a close relationship between innovations and alternations in prosperity. Thus Professor Josef Schumpeter holds that innovations begun by a few able minds and followed by many imitators stimulate prosperity, which in turn stimulates more inventions.[34] A. B. Adams likewise suggests that the introduction of new competitively superior capital equipment may help to initiate a business cycle.[35]

VI, Shifting Occupational Patterns, in *Recent Social Trends*. For divergent interpretations of the theoretical possibility of permanent technological unemployment, see: Paul H. Douglas, Technological Unemployment, *American Federationist,* August 1930, pp. 923–50; and Alvin H. Hansen, *Economic Stabilization in an Unbalanced World,* Ch. X, Institutional Frictions and Technological Unemployment. Douglas expounds the optimistic expectation that decreased requirements for labor arising from technological change merely shift purchasing power to other uses where equivalent new employment opportunities will be created. Hansen stresses the possibility that the institutional controls of the present-day industrial organization, notably those which help to account for the relative rigidity of wages, are likely to create lags in the absorption process and, under certain conditions, may even result in a failure to reabsorb displaced workers.

[34] *Theorie der wirtschaftlichen Entwicklung,* 2d ed. (1926), Ch. VI.

[35] *Economics of Business Cycles,* pp. 138–50.

It does appear possible that the increased productive capacity accompanying an improvement of plant equipment may intensify competition, and by that very intensity tend to periodic irregularity in operation. For example, the press has been, at times, filled with ominous hints of an impending price war in a struggle for the market between leading automobile producers whose combined full capacity, it is urged, far exceeds any demand that may reasonably be expected.

Also, advances in mechanization lengthen the chain of productive processes intervening between the raw materials and the final use of goods and thus increase the possibilities of misadjustment of production to effective consumer demand.

Furthermore, whatever may be the causes of cyclical fluctuations, the production of capital goods is one of the highly variable elements in the productive process. As computed by Dr. Mills, the index of instability of growth in the period 1922–29 was 1.4 for non-durable consumption goods, 2.7 for semi-durable consumption goods, 6.2 for durable consumption goods and 6.6 for machinery.[36] The expansion in the machinery industries which accompanies increasing mechanization is an expansion of a highly variable element in the industrial system.

On the other hand, so far as the interests of the user of machinery are concerned, a high mechanization of his processes involves heavy overhead costs and increases the incentive for maintaining in all possible ways regularity of operation. Men may be laid off without pay, but machines may be stopped only at the expense of their owner.

[36] *Op. cit.*, pp. 270–8; see also Ch. VIII *supra.*

SEASONAL IRREGULARITIES

In construction work mechanization helps to iron out seasonal irregularities by furthering cold weather operation. A power shovel can be used for excavation in temperatures that would make hand shovels impracticable. Likewise, other changes in the building industry, such as the use of structural steel, have made it possible to do much of the work in the shop prior to erection, thus lessening human exposure and furthering winter work.[37] In the window-glass industry the introduction of the machine has made possible operation throughout the hot summer months. The substitution of steam-pipe-rack driers for open-air 'summer yards' in brick making has lengthened the operating season for brick yards. Manufactured ice may be made the year round; natural ice is frozen only in winter.

An interesting example of a possible increase in the seasonality of operation through further mechanization arises in the sugar beet industry. The invention of a practical beet puller and topper for use in the autumn harvesting is rendered less desirable by the necessity of using hand labor—largely migratory Mexican workers—in the summer in thinning the beets. As the same workers are used in the autumn work of pulling and topping, the mechanization of this autumn work would make the hand work in the beet fields more seasonal than it now is, increasing the present difficulty of securing an adequate force for the thinning period.

[37] *Cf.* discussion of this point in the report of the committee of the President's Conference on Unemployment, *Seasonal Operation in the Construction Industries, Report of the Industrial Commissioners* (New York State), *1928*, p. 164; Ralph J. Watkins, *The Construction Industry in Ohio*, p. 148.

Effect on Skill

We are primarily concerned here with manual as distinguished from clerical, managerial and professional workers. Manual workers may conveniently be classified as skilled, semiskilled, and unskilled or common laborers.[38] Skill is a quality which is not precisely defined, and the available quantitative evidence concerning the relation between the progress of mechanization and changes in the degree of skill in industry is relatively scant and fragmentary. However, on the basis of information collected in our interviews and correspondence with factory executives or presented in the literature dealing with industrial change, we can submit at least tentative formulations of the effects of mechanization on skill.

It is quite possible that a new device may lower the grade of labor in the operation directly affected but raise the general average because of the skilled labor required in the production, maintenance and repair of the machine. Hence, we can more readily appraise the net effect of the progress of mechanization if we direct our attention to three aspects: (1) the amount and grade of labor in the production of machines; (2) the amount of skilled labor engaged in machine repair work; and (3) the effects of mechanization on operating labor.

LABOR IN THE PRODUCTION OF MACHINES

In the post-War decade about one million men were employed in the production of machines (Table 21, Ch. VI). In Chapter VIII we cited evidence to indicate that the grade of skill in machinery factories is somewhat higher

[38] The customary significance of these terms is analyzed in Ch. VIII, section on Grade of Labor in Machine Production.

than that in the manufacturing industries as a whole, and also estimated that on the average the percentage distribution of all workers engaged in machine production, directly or indirectly, is: unskilled 25, semiskilled 55, and skilled 20.

Obviously, the machine which displaces only one type of worker will reduce the proportion of that type in industry as a whole but will raise the proportion of the other two types, to the extent that workers of those types are employed in the production and repair of the machine.

LABOR IN MACHINE REPAIR WORK

The use of more machinery or of more intricate devices doubtless, as a rule, increases the proportion of repair and maintenance labor, both by decreasing the amount of operating labor and by increasing the repair and maintenance labor. For example, the number of looms to each loom fixer in cotton mills is ordinarily less for automatic than for nonautomatic looms; and automatic telephone switchboards require more maintenance labor than the manual type.

However, the reverse—a decrease in repair labor—is sometimes one of the incentives for the installation of new types of equipment. Some of our informants stated, for example, that one reason for their adoption of the individual motor drive was that it requires less maintenance and repair labor. Also, early models of a new type of machine often get out of repair more readily than later, more ruggedly constructed models. However, though the progress of mechanization sometimes reduces the absolute amount of repair labor, probably even in such instances it ordinarily increases the proportion of repair to direct operating labor.

The repairing and adjusting of machines requires a relatively high degree of skill. We estimate, roughly, that in the typical factory 3 to 5 per cent of the labor force are skilled men on machine repair work. This estimate is based on replies to a special inquiry received from 88 of the establishments included in our survey (Ref. 20–a). These establishments manufactured a wide variety of products, in which textiles, furniture, secondary iron and steel products, brass goods, motor vehicles and smelting and refining predominated. Their replies showed that 4 per cent of their total labor force of 42,348, or approximately 15 per cent of the total number of their skilled workmen, were on machine repair work.

The wording of the repair question differed slightly in the several industries, and as a result it is likely that a small amount of building repair work is included in these figures. Nevertheless, the percentage shown is probably an understatement, because some machine repair work is done by men whose primary job is the operation of machines; also, especially in large cities, much repair work is done by service men in the employ of the machine manufacturers. Doubtless in some industries, particularly those which are highly mechanized, the proportion of repair labor is substantially higher than indicated by the above estimate.

EFFECTS ON OPERATING LABOR

To minimize the chance of misleading generalizations, we shall discuss in turn four types of labor-saving changes: 1. innovations in handling methods that do not materially alter the nature of the processing operations or the facility with which they are carried on; 2. handling changes that by reducing the flow of materials to orderly sequence tend to systematize and standardize the processing operations and hence may alter both the grade and amount of processing labor; 3. changes in the processing operations that directly displace handicraft procedures by mechanical devices; 4.

changes in the processing operations that merely introduce improved mechanical devices or methods in operations already mechanized.

Modifications in handling methods only

The workers engaged in the handling or transportation of materials in the factory are relatively unskilled, particularly where such operations are manually performed (Ch. V). Hence, in the case of those handling changes which do not also modify or speed up the processing operations, the substitution of mechanical for manual handling tends to increase the proportion of relatively skilled workers, both by decreasing the total number of workers engaged in handling, most of whom are unskilled, and by increasing the number of semiskilled and, in some instances, even of skilled workers. The operator of the industrial truck, the power conveyor or the overhead traveling crane would ordinarily be classed as at least a high-grade common laborer or as a semiskilled worker and in some instances as a skilled worker.

For 31 instances of labor-saving innovations in handling reported to us (Ref. 20–a), the data enable us to compute the change in the number of workers of each grade. The aggregate reduction was from 535 to 134, or about 75 per cent of the total force engaged in the specified handling operations. The number of unskilled workers was reduced from 523 to 64, the number of semiskilled was increased from 56 to 61, and the number of skilled from 7 to 9.

In addition to the indicated increase in the proportion of semiskilled and skilled laborers directly on the handling operations, the use of machines for handling necessitates some relatively skilled labor for their initial construction,[39]

[39] The following summaries of the grade of labor in three plants producing handling and excavating machines that displace common labor serve

for their maintenance and repair, and for the production of the power used; hence it would seem to be quite well established that the type of handling device which affects only handling operations tends to widen the market for high-grade labor.

Handling innovations that systematize the processing operations

Some improvements in handling facilitate labor saving in the processing as well as in the handling operations. A basic feature of much of our modern mass production is the serialization of machines and processes in such a way as to reduce handling to a minimum and arrange the assembling and other processing operations along a continuously or intermittently moving conveyor, with the processes highly subdivided and standardized.[40] Such changes in handling

to illustrate the tendency for such machines to require a higher grade of labor in their production than that displaced by them.

Plant No. 1 produces industrial electric trucks. The manager of this plant stated that he employs very few common laborers and that about 90 per cent of his force is skilled.

Plant No. 2 produces bucket loaders, narrow trench diggers and other machines that do the work of unskilled labor. As it buys its castings, the labor cost directly in the plant is only a small percentage of the cost to consumers; but 47 per cent of its labor is skilled, 45 per cent semiskilled and only 8 per cent unskilled.

Plant No. 3 produces a narrow trench digger that takes the place of hand-shovel labor. About 25 per cent of its force is common labor, the remainder semiskilled and skilled.

40 See also Ch. V. It may be noted that the tendency towards greater subdivision of work is not necessarily associated with increased mechanization. For example, in the manufacture of cotton cloth, some plants in recent years have introduced a higher division of labor, assigning, for example, more looms to a weaver, but delegating his less specialized tasks to less skilled and lower-wage workers, thus lowering the general average of skill required in the weave-room force—all without necessarily making major changes in the mechanical equipment. See also the discussion of subdivision of labor in a rubber shoe plant, Ch. III, Shoes, footnote 57.

methods not only reduce the amount of handling labor, but also tend to make possible the use of more narrowly specialized workers on the assembling and processing operations. They encourage the production of standardized products such as interchangeable parts, and, in general, further the substitution of production planned and systematized in detail by engineers and executed by semiskilled workers for production dependent upon the artisanship of high-grade mechanics.

In changes of this type there may be a two-fold reduction in the direct demand for skilled workers on the immediate processing operations: the work can be done by less skilled operators and the output per man is increased.

There are mitigating factors. The introduction of this type of operation has largely been in the rapidly growing industries, such as automobiles and tires, and hence has not meant the actual displacement of skilled workers to the extent that would be involved in a similar change in industries expanding less rapidly. Also, the effect on operating labor is, of course, as in other developments in mechanization, partly offset by the increases in the use of skilled labor in machine production, maintenance and repair.

Displacement of manual by machine processing

Where the mechanization of a process involves the substitution of a processing machine directly for the handicraftsman, it is probable that the typical effect, even after allowing for indirect as well as direct effects, is a net decrease in the grade of skill required.

This tendency to decrease the need for specialized skill finds classic illustrations in the history, as recorded by Professor George E. Barnett, in his *Machinery and Labor,* of the introduction of the stone planer and the semiautomatic and automatic bottle machines. The glass industry affords other examples of the relatively recent supplanting of skilled labor by machines. The cylinder machine for window glass displaced the two highly skilled trades of gathering and blowing, and the semiskilled trade of snapping. True, it introduced a few new crafts requiring considerable skill, but they involve only a few workers. The introduction of machine molding likewise tends to enable semiskilled workers to do the work of an even larger number of skilled workers, and the casting method of making sanitary ware, which has come into extensive use since 1922, lessens the dependence on the skilled potter as compared with the hand pressing method which it supplants. The evolution of the cigar industry from completely manual processes to almost completely automatic machines has been marked by the substitution of semiskilled workers for the skilled cigar maker and has increased remarkably the proportion of women and children in the industry.[41]

The potential displacement of skilled labor by the further substitution of machine methods for hand processing is limited by the fact that, while there are still many hand workers in industry, the number engaged in hand crafts that are of a distinctly skilled type is relatively small, especially if we exclude the building industries; hence any further reduction in the demand for skilled labor due to the direct substitution of machines in skilled hand crafts is apparently not the major problem in judging the probable effect of further mechanization upon skill requirements.

The transition to mechanical processing does not always affect the level of skill adversely. If the displaced manual

[41] John P. Troxell, Machinery and the Cigarmakers, *Quarterly Journal of Economics,* February 1934, pp. 338–47.

methods require only semiskilled or even common labor, then mechanization tends to raise the proportion of skilled workmen. For example, the warp tying-in machine, used in cotton weaving, enables a skilled machine operator, with an assistant, to do work formerly requiring 12 to 18 tying-in girls. Their work required considerable adeptness and experience, but not a degree of skill comparable with that required of the machine operator. The following examples from our factory inspections will serve as illustrations of innovations that displace semiskilled rather than skilled workers:

Plant No. 54, high-grade sporting guns. One man of the semiskilled grade operating a sanding machine does work that formerly required 5 men of the same grade.

Plant No. 103, machine screw products. One semiskilled woman operating a screw-sorting machine does work formerly requiring 10 semiskilled women.

Plant No. 105, typewriter ribbons. With a ribbon-reeling machine, 3 semiskilled men do work formerly requiring 9 semiskilled.

In a group of 8 plants, 14 semiskilled workers operating various wrapping, packaging, nailing and labeling machines do work formerly requiring 74 semiskilled workers.

Also, if operations which have already been reduced to progressive assembly or progressive processing advance to a more highly mechanized stage where mechanical devices displace some of the manual workers along the assembly line, the change is likely to reduce the number of semiskilled operatives, and tends, on the whole, to increase the demand for skilled workers and trained technicians in the construction and planning departments.

For example, a factory as highly mechanized as the A. O. Smith Corporation automatic automobile-frame plant requires much skilled labor in the planning and engineering departments but relatively few workers in the immediate operation of the machinery.[42]

[42] L. R. Smith, We Build a Plant to Run Without Men, *Magazine of Business*, February 1929, pp. 135–8, 200.

Improvements in processes already mechanized

The effect of those labor-saving changes that involve the substitution of one mechanical method for another is most difficult to appraise. Some improvements change the character of the remaining work and thus alter the qualifications required of the operating workers; more frequently they merely reduce the number required. In general, minor improvements in the equipment used in operations already mechanized, such as increases due to faster machinery or larger units, and to automatic feeding devices, rather than to essential changes in the type of equipment or process, reduce the relative demand for the particular grade of operator required, and in the majority of instances this is the semiskilled type.[43] For example, the 'automatic spooler and high speed warper', now being introduced into the cotton goods industry cuts the requirements for spoolers and warpers, who are semiskilled operatives, approximately in half.

A clue to the net effect when we consider not only the operating labor but also the labor involved in the production of the machines that displace semiskilled labor is afforded by the following examples from our inspections:

Plant No. 4 produces textile labor-saving machinery that displaces semiskilled workers. Of a total of 850 workers, 450 are skilled, 350 semiskilled and 50 are common laborers.

Plant No. 5 produces automatic textile looms that increase the output of a relatively high grade of semiskilled workers. The percentage distribution of the labor force is: skilled 25, semiskilled 65, and common labor 10.

Plant No. 6 also produces automatic looms. In the machine shop and

[43] The net effect of the technical changes in the pressrooms of commercial printing establishments in recent years, chiefly in the introduction of high-speed, self-feeding, 'job-automatics' and the addition of mechanical feeding attachments to other types of presses, has been to increase the proportion of the highly skilled pressmen to the less skilled assistants (Baker, Ref. 5).

foundry combined about 40 per cent of the workers are skilled, and 60 per cent semiskilled or unskilled.

In each instance a substantial proportion of skilled workers is required in the production of these machines, but they displace almost entirely semiskilled labor.

When we take into consideration the proportion of skilled workers in machine construction and repair, it seems probable that, on the whole, improvements in processing operations already mechanized increase the total demand for skilled workers.

SUMMARY OF EFFECT ON SKILL

Any conclusion as to the net effect on skill of further mechanization, when all of the several types just discussed are lumped together, is necessarily a more or less impressionistic judgment based on a totality of observations, not all of which can be reduced to tangible form. If we compare industry in its present stage with manufacturing prior to 1900, when a period of apprenticeship was the customary gateway to an occupation, it is possible that the average skill and initiative required of the worker has declined. On the other hand, with industry mechanized to the extent that it was in this country by the close of the World War, the net effect of the changes of the last decade is not so clearly one-sided. The numerical evidence, admittedly limited, assembled in our survey indicates that the mechanization of handling has tended to reduce the proportion of unskilled workers in industry; that in the direct displacement of handicrafts the mechanization of processing has ordinarily reduced the demand for certain types of skilled workers; but that the innovations in processing operations have in many industries made no sweeping changes in the proportions between common, semiskilled and skilled labor. Probably the aggregate effect may be accurately described as a leveling process producing fewer highly skilled jobs but also few really unskilled jobs.

From executives of 101 manufacturing establishments we obtained answers to the following question: "For the single change made since 1920 which resulted in the greatest saving of labor . . . was the labor saved of the unskilled, semiskilled or skilled grade?" [44] The reduction was effected in the skilled grade in 25 per cent of the total number of reports, in the semiskilled in 43 and in the common labor grade in 32. The percentage with reductions in skilled labor was 36 for the processing operations and only 10 for the handling operations. On the other hand, changes resulting in reductions in common labor constituted only 18 per cent in the processing operations and 52 in the handling.

Evidence in a slightly different form is afforded by 114 labor-saving innovations for which we obtained information adequate to enable us to determine whether they lowered, raised, or made no change in the grade of operating labor required (Ref. 20–a). In 69 instances the change did not alter the type of labor required.[45] About four-fifths of the instances of lowered skill were reductions from the skilled to the semiskilled grade. The advances in skill were chiefly substitutions of semiskilled workers for common labor. Of 39 labor-saving changes in handling equipment and methods for which our informants stated the grade of labor before and after the change, 3 lowered the grade required, 24 made no substantial change, and 12 raised the skill re-

[44] The definition of these terms was left to the judgment of the informant. For discussion of the meanings ordinarily assigned by factory executives, see Ch. VIII, section on "Grade of labor in machine production".

[45] In the operations involved in these 69 changes, skilled labor was employed in 8, semiskilled in 28 and common in 14. The information at hand is inadequate to classify the labor in the remaining 19.

quirements for all or part of the crew, chiefly by substituting semiskilled workers for unskilled.

On the other hand, in 45 labor-saving changes affecting the processing operations and involving an aggregate reduction in force from 965 to 355, the number of common laborers was reduced from 36 to 6, semiskilled from 698 to 331, and skilled from 231 to 8. Here the proportionate reduction was relatively greatest for the skilled group, although numerically greater in the semiskilled. This sample was rather heavily weighted with the foundry industry, and most of the reductions in the demand for skilled workers was in foundries. In the non-foundry plants, the changes in processing methods affected the three grades of workers in about the same proportion.

The evidence afforded by these two samples suggests that a large proportion of labor-saving changes reduce the number in the given operation without altering the grade of labor required, and that innovations reducing the grade occur chiefly in the processing changes; those raising the grade, in the handling changes.

As to the effect on skill of further mechanization in the future, with our industries in their present state of mechanization there is considerable reason to believe that the effect of further changes will be to raise the average skill required. The construction, installation, repair, maintenance and adjustment of machines (including automobiles) is requiring an ever-increasing army of relatively skilled men; the number of skilled men still engaged in hand processes, aside from the building operations, is relatively small; a further displacement of unskilled workers by mechanical handling may be expected; and so large a proportion of other workers in industry are now semiskilled that the principal effect of further mechanization of the processing operations will be to decrease the demand for semiskilled workers. The effects will, of course, be diverse, some changes lowering the skill requirements, others raising them. On the whole, the shift will continue to be from emphasis on the trade skill typical of the handicraftsman to, on the one hand, the alertness and intelligence required in handling fast and intricate machinery and, on the other, to the more formal training required in the engineering and production planning departments. In the machine repair men we shall continue to have an approximation of the type of training and skill required of the old-style all-round mechanic.

In this section we have been discussing primarily the effect of mechanization upon the general average of skill in industry. Nothing here said should be construed as overlooking the obvious fact that even a change which raises the general level of skill may result in skill obsolescence and pecuniary losses for the particular individuals trained in the out-moded methods.

Other Effects of Increasing Mechanization

We have noted above the effects of labor-saving improvements upon skill requirements. In the course of our examination of the facts of mechanization, our informants have called our attention to various other savings which they attribute to particular labor-saving changes in equipment or methods.

In all, 148 instances of effects of labor-saving changes other than the direct effect on the quantity or grade of workers employed were reported to us. In 34 instances, the quality of the final product or of semi-finished goods at some stage was improved; in 25, the capacity of the plant was enlarged by increasing the output of 'bottle-neck' departments (12 instances), by reduction of stoppages (7), and in various other ways. In 24 instances, working conditions were improved by lightening the tasks, by making possible cleaner or safer working conditions, and in other ways. Space requirements were reduced in 13 instances, fuel or power saved in 9, the breakage or waste of materials reduced in 17, and repairs and maintenance in 16. Reduction in the volume of work required in departments other than the one in which the equipment change occurred, and miscellaneous other savings complete the list.

Obviously the instances cited are not quantitatively adequate to indicate whether the tendencies listed are generally associated with the progress of mechanization; but they will serve to call attention to the great diversity of factors which must be taken into consideration in appraising the totality of effects resulting from changes in equipment or processes.

CONDITIONS OF WORK: MACHINES AND INDUSTRIAL HEALTH

That machinery is responsible for a substantial proportion of industrial accidents will be granted. For example, in New York State in the year ending June 30, 1927, 13 per cent of all accidents were attributed to machinery, and the burden of machine accidents was particularly heavy for boys—22 per cent.[46]

However, where increases in accidents have occurred, the increase has not been restricted to machine accidents; in fact, in New York State

> "in the five years ended June 30, 1927, machine accidents increased 28 per cent, but all types of permanent injuries to eyes, hands, feet, etc. . . . increased 80 per cent. In two types of machines where the hazard and the resulting injury were greatest the greatest improvement was evident. This was in power presses and buzz saws."[47]

[46] *Industrial Bulletin,* N. Y., June 1928, p. 276, Machinery the Chief Cause of Accidents to Minors.

[47] N. Y. State Department of Labor, *Report of the Industrial Commissioner,* 1928, p. 3.

The bearing of increasing mechanization upon safety in industry is analyzed in the report of the American Engineering Council on *Safety and Production* (Ref. 1). As this report points out, we are confronted with the apparent paradox that while on the one hand the most efficient operation of a plant depends on continuous operation, which in turn is contingent on safety, yet in fact the critical situation which led to the study consisted essentially in the circumstance that the intensive development of industry in the post-War period appeared to have been accompanied by an increase in the number and severity of accidents. In the introductory statement of the report, Mr. Whitney suggests that mechanization undoubtedly affects the accident situation in many ways, some of the effects being favorable, some unfavorable. Among the unfavorable factors he suggests (pp. 5–6):

"1. The introduction of machinery has, in many cases, displaced hand-work that was comparatively safe. Even though the change may have resulted in accomplishing the work in question with less sacrifice of life and limb, the hazard per worker, because of the greatly decreased number of workers, is, in general, greater. Not only is the number of machine accidents per worker greater, but the severity is greater than under non-mechanized conditions."

"2. The introduction of automatic machinery has, in general, had the effect of displacing operators that were working under standardized conditions at machines that could be thoroughly guarded. The man-power that is needed on automatic machinery, on the other hand, is largely for repair work. Such work is intrinsically dangerous and is scarcely capable of being standardized."

"3. Under mechanized conditions the speed with which material goes through the process of manufacture is increased and the exposure to accident, other things being equal, is proportionately greater."

This report makes comparisons between production and accident rates in 1922 and 1925 of 359 companies in 34 industries and employing 254,529 workers. About 80 per cent of the companies showed an increase in the rate of production and a decrease in both the frequency and severity of accidents in 1925 as compared with 1922; but for the group as a whole it was found that:

1. productivity increased 14.4 per cent;
2. accident frequency per man-hour decreased 10.4 per cent;
3. accident severity per man-hour increased 2.5 per cent.

It may be that the increase in severity observed in the period studied is due primarily to the higher degree of mechanization reached; but in the judgment of the writer it should be ascribed in greater part to the rate of change in this period, as a temporary increase that may be cancelled when a slackening in the rate of change gives the safety movement a better opportunity to catch up. Certain it is that industrial hazard is not solely a machine phenomenon, nor are the more hazardous occupations restricted to the mechanized tasks.[48] In fact, in some instances an increase in the degree of mechanization reduces the health hazard.[49] Doubtless, however, the development of adequate protective devices and methods frequently lags behind the development of new processes or new equipment, and the knowledge or fear of this lag in some degree retards the introduction of new devices.

ARDUOUSNESS OF MACHINE LABOR

Mechanization has been charged with making the life of the factory worker well-nigh intolerable, and credited with lifting the heaviest burdens from his back. In the steel mills,

[48] Compare the discussion of this point and other phases of the relation of mechanization to health in Stuart Chase, *Men and Machines*, pp. 148–55.

[49] For example, a paint factory included in our survey has substituted the mechanical handling of litharge under cover for manual handling primarily as a means of avoiding the danger of lead poisoning. Likewise, it is claimed for some of the newer developments in materials handling in construction and factory operations that they reduce the accident hazard.

according to the conditions described by John Fitch, machinery is doing much of the heavy drudgery, but the legacy of this development has been a terrific din of machinery and an unremitting nervous strain in handling the mechanical devices with due care and precision.[50] Much could be said with respect to these two sides of the problem.

We shall not attempt here to strike a balance between modern machine industry and a complete handicraft system. We are concerned rather with relatively recent and impending changes in the degree of mechanization. The writer is inclined to believe that the net effect of these changes is to improve the conditions of work and lighten the physical burden of the worker. In the course of our survey various examples of a conscious effort on the part of many executives —apparently an increasing effort—to eliminate hand processes involving excessively arduous or disagreeable work have come to our attention.[51]

The tendency to substitute oil for coal as fuel, or electric power for steam power has reduced the number of laborers engaged in the arduous work of stoking furnaces; and the extensive introduction of mechanical handling devices has shifted to the machine much of the heavier trucking and lifting work of the factory. Likewise, many special developments in processing machines tend to reduce the task of the operator to that of merely seeing that the machine is functioning properly.

Against such gains it is urged that the tendency towards standardization of machine processes, such as is exemplified in the continuous-assembly-belt system, introduces or in-

50 *The Steel Workers,* p. 58.

51 The manager of a ship and engine company mentioned that the introduction of the electric furnace in their foundry has improved conditions sufficiently to make it appreciably easier to get American workmen who formerly avoided the foundry.

tensifies the element of fatiguing monotony. Even here, however, the tendency is to minimize the exertion of strength and the exposure required of the worker.

EFFECTS ON QUALITY

The effects of increasing mechanization on the quality of products is admittedly a moot question in many instances, and no all-inclusive generalization can be made.

In general, where standardization is desirable, the machine product is more satisfactory than the hand-made. The superiority of the machine is especially marked where the adherence of a large number of units to minute specifications is required. The output of modern machine tools, for example, can be held to a precision unattainable in handicraft work; and in many even less exacting cases of standardization the superiority of the machine is conclusive. For example, automatic weighing and packaging devices make possible greater uniformity in content.

Improvements in quality mentioned by informants interviewed in the course of our field survey include, among others, the following pertinent instances:

The system of automatic control for mixing pulp for newsprint paper adopted in recent years is said to result in a more uniform product than from the former manual control of mixing. In cotton cloth manufacture the work of the machines in drawing-in and tying-in is said to average more uniformly good than hand drawing-in or twisting-in; there are always some poor hand workers. In highway construction the subgrade can be shaped more accurately with the mechanical subgrader than by hand. In demolishing sections of hard-surface pavement for repair purposes, it is claimed that with the pneumatic hammer, the cutting tool can be set to cut uniformly to a desired depth and also that cutting to a line can be more readily done. The substitution of power for hand irons in pressing the edges of coats in the manufacture of men's garments is reported to result in a more accurate pressing of the unfinished garments and consequently better work in the subsequent stages. The introduction of mechanical screening plants in retail coal yards has, in the several cases reported, made possible a more satisfactory sorting of the fine coal and its sale at better prices. In several instances, machine molding equipment was reported to give a more uniform casting. An automatic rim-grinding machine on car wheels resulted in a more uniform job. Mechanical sanding devices on wood operations were reported to improve the quality of the product; and the use of automatic distributors to cotton lapping machines results in more even laps than from hand feeding.

"The very great improvement in the quality of tubing effected by the machine," when combined with a large increase in man-hour output and a decrease in labor costs, has "resulted in the almost complete elimination of hand production in favor of the machine." [52]

Where the process involves pressure somewhat too high for easy manipulation by hand, the use of mechanical devices is likely to result in a more uniform product. Thus it is claimed that the automatic dumping device on molding machines improves the product as compared with the hand-dump because a stiffer mud may be used. Likewise, in the production of floor and wall tile the tile press compresses the damp granular clay much more compactly and more uniformly than the hand press, raising the quality of the finished tile.

But the story is not at all one-sided. Doubtless many machines are sub-marginal because of their wastage of ma-

[52] B. L. S., Ref. 36, pp. 137 ff.

terial or the poor quality of their products, and are pushed into the class of economical devices only by changes in the price of the product,[53] in wage costs or in other major elements in the cost of production. Whenever high quality rests not upon standardization but upon adaptation of a process to a constantly changing and wide variety of conditions, the odds in favor of the machine materially decrease or disappear.

For this reason, in the growing of sugar beets the mechanical beet blocker and the mechanical beet topper still cannot compete satisfactorily with hand work, and for similar reasons in such industries as meat packing, where the work consists largely of the dismembering of carcasses, each one varying somewhat from those immediately preceding and following, a large proportion of handwork survives. One obstacle to the development of mechanical cotton picking has been that machines of the simpler and relatively inexpensive types do not gather only the ripe bolls but harvest the entire crop at one time indiscriminately. It is claimed that the hand-made lamp-chimney is of better quality than the machine product because of greater facility in incorporating a variation in the thickness of the glass in the various parts of the chimney.[54]

The advantage of the machine, and the standardization associated with it, is less clear in consumption than in production goods, and undoubtedly a preference exists, sometimes well-founded, sometimes perhaps not, for hand-made products. Frequently a machine-made product, whether a pro-

[53] A sharp impetus was given the use of the cotton 'sled' or stripper in northwest Texas when in the season of 1926 the cotton farmers found themselves confronted with an unusually large crop, high wages and declining cotton prices. See D. L. Jones, *et al., Mechanical Harvesting of Cotton in Northwest Texas,* Circular No. 52, Texas Agricultural Experiment Station, p. 26.

[54] B. L. S., Ref. 36, p. 114.

ducers' or consumers' good, encounters a prejudice in the early stages of its introduction which later decreases. This prejudice arises in part from the crudity often characteristic of machine products in the early stages and in part from a traditional prejudice in favor of the hand-made product.

For example, the effects of mechanization in the window-glass industry is a matter of dispute so far as quality is concerned, but the belief, at least, seems to have persisted for some time that the mechanical processes resulted in a larger proportion of poor glass, making difficult the cutting of an equal number of large pieces from a specified output. Likewise, in the use of milking machines in New Zealand, H. L. Russell and Theodore Macklin report that "when the machines were first introduced, considerable trouble was experienced in keeping the teat cups and the releaser pipes in a thoroughly sanitary condition", with a resulting "dish water taint" in the milk, but that later "this obstacle has been met by the use of electricity to heat wash water to the boiling point." [55]

It may be impossible to strike a balance on the score of quality; however, we shall not be far wrong if we generalize by saying that the superiority of machine products intended for use in further production in standardized processes is quite readily recognized, but that the introduction of machine products to replace hand-made goods in the field of consumers' articles will ordinarily be limited or retarded by a preference, fully justified or not, in favor of the hand-made product. We are not overlooking the fact, of course, that in many lines, particularly commodities like sugar, salt and many other foodstuffs, machine-made products virtually monopolize the field. We speak rather of the prejudice to be expected when a machine product invades a new field.

[55] *Intensive Dairying in New Zealand and Wisconsin,* Bul. 377, Agricultural Experiment Station, University of Wisconsin, 1925, pp. 16–7.

EFFECT ON SPACE REQUIREMENTS

Small-scale fabrication frequently can be carried on by hand in shops that would be too small for the minimum economical size of a machine-equipped plant; and a certain minimum width of aisles and height of rooms is frequently essential to machine operation. But, particularly for operations on any considerable scale, machines usually require less space than is essential to turn out the equivalent product by hand methods.

Further reduction of space requirements with increasing efficiency in type or operation of machines occurs along two lines. First, the speeding up of machines without any essential change in their type or size results in a greater output with essentially no change in floor space except as required for handling and storing the increased output. Second, while many of the improved models of machines are larger units, they are likely to require less space than the several smaller units which they replace.

Let us note a few illustrations of the tendency frequently evidenced for mechanization to reduce space requirements:

1. The extensive introduction in recent years of mobile power trucks and of overhead conveying systems for handling materials has in numerous instances relieved the congestion in floor space, particularly in aisles, caused by the numerous hand trucks and the piles of material accumulated for them.
2. The machine piling of lumber and the mechanical handling of bricks make feasible higher piles and thus reduce the required yard space.
3. Power screening plants for handling retail coal were reported to us as saving ground space.
4. The use of tractor power, instead of horses, in highway construction is said to lessen the confusion and crowding on the subgrade.

5. The increasing substitution of oil for coal as boiler fuel is reducing the required yard storage space.
6. The increasing substitution of individual motor drives or purchased current for steam power and shaft drives is making possible a more compact machine arrangement.
7. Frequently, new models of machines are less bulky and clumsy than earlier models. The latest model of the Westlake machine for electric light bulbs involves changes that appreciably reduce its weight and bulk; output is thereby increased owing to the consequent higher speed of rotation.[56] The substitution of the new-style 'automatic spooler and high speed warper' for the older and slower styles of spoolers and warpers has resulted, we understand, in a reduction of required floor space of about one-half.

OTHER FACTORS WEIGHED BY THE FACTORY MANAGER

While we may not assume that the factory manager is always actuated solely by economic motives in adopting or rejecting a new machine or process, yet it is reasonable to assume that any anticipated effect of the innovation upon pecuniary returns will be taken into consideration. Hence, in addition to the effects already mentioned in this chapter, his decision will rest in part on whether he believes the new machine will require more or less power, waste more or less material, require more repairs and maintenance, increase or decrease his labor turnover, make possible a speedier completion or a more certain completion of tasks on scheduled time or, perhaps, make possible a fuller utilization of other equipment by minimizing stoppages or by enlarging capacity at a particular 'bottle neck' in the process—that is, a department with capacity not adequate to feed material properly to subsequent departments.

[56] B. L. S., Ref. 36, p. 125.

Fuel or power requirements

The initial substitution of mechanical methods for handicraft work obviously increases the requirements for fuel and power; but as machine methods are improved these requirements are frequently decreased. This is particularly true in the use of fuel in the production of power itself. The reports of the Geological Survey indicate a substantial decrease in recent years in the quantity of coal required to turn out a kilowatt of power. In fact throughout industry we find various instances of improvements tending to reduce the quantity of fuel or power required. Here we may class the introduction of waste-heat boilers in cement plants, and the introduction of continuous annealing ovens and brick kilns.

Waste of materials

The introduction of a new process is sometimes retarded by the belief that it would cause more materials to be wasted. On the other hand, numerous instances can be cited where improved methods of processing or of conveying materials reduce the amount of breakage and wastage involved. It is claimed for the mechanical vegetable peelers that they reduce the waste on potatoes as compared with hand peeling some 60 per cent; and that the mechanical handling of brick reduces breakage. A furniture factory reported a 50 per cent saving in lumber in certain operations by the introduction of mechanical molders and planers. A foundry reported that the substitution of straightening presses for the drop hammer method in straightening castings reduced the loss of castings.

Repairs and maintenance

We have elsewhere discussed the diverse effects of modern mechanization tendencies upon the amount of repairs. On the one hand, the increasing intricacy of machinery increases the amount of repair labor. On the other, the observed tendency towards the development of more rugged models decreases the maintenance requirements. On the whole, a substantial degree of ruggedness is an essential for the extensive commercial adoption of most mechanical contrivances; and the ability of new devices to ensure more regular operation is always a strong factor in their favor.[57]

Control of production schedule

Does the increasing mechanization of factories make the employer more certain of the completion of an order on schedule time? In certain instances this seems clearly to be true. It was pointed out to the writer, for example, by executives of some of the factories inspected, that the installation of a machine in place of a group of hand workers on a key job decreases the dependence on labor, in the sense that the chance of mill stoppage due to a strike at the key point is much less. In other words, a machine operator or two are less likely to go on strike than a group of 20 or 25 workers engaged on a common occupation and with common interests. Likewise, some road contractors gave as the reason for the purchase of additional machinery the desire to make more certain the completion of work within the contracted period. The machine does not quit in search of higher wages elsewhere; hence, if ruggedly built, it promises somewhat more continuous operation.

[57] The makers of steam grate shakers claim, for example, that grates of locomotives in terminal ash pits can be shaken more quickly by steam than by hand; consequently, the engines may be kept more constantly in active operation. Likewise, wagon loaders save the time of trucks when loading materials from ground storage and thus facilitate a more economical use of the trucks.

Increase in the capacity of other departments

Frequently a mechanical change in a given department not only increases the output of that department but by causing a better balance of equipment increases as well the effective capacity of other departments or of the plant as a whole. Among the labor savings reported to us were a number of instances of such expansion due to the improvement in a 'bottle-neck' department.

Other Considerations

Obviously, the preceding discussion of the effects of mechanization does not even touch upon many of the ways in which the increasing use of machines alters for better or worse the social and cultural life of the modern world. Even on the economic side, there are many additional questions which may appropriately be mentioned, although no attempt is made to answer them in this monograph. Does mechanization tend to reduce labor turnover? Is the ability of American manufacturers to compete in world markets largely due to the development of mechanical devices which supplant expensive and laborious manual effort? Is the increasing productivity arising from mechanized mass production really as great as it seems; to what extent is it true that the development of mass production, with its dependence upon extensive markets, brings with it indirect expenditures of labor which are not ordinarily allowed for in computing the changing efficiency of industry? To what extent, in other words, are manufacturing economies offset by increasing distribution costs? Will increasing mechanization, by lessening the labor force required, facilitate the deurbanization of industry and make it less dependent on a floating labor supply? Does the increasing use in recent years of individual electric motors driven largely by purchased power, encourage such decentralization of industry or its greater concentration in industrial centers? Is it probable that, just as the urban civilization of the last century or so has been built upon mechanical power, the inventions and developments of the present century may reverse the process and bring the restoration of an industrial rural life and the revitalization of the small community?

These suggestions of a few of the broader aspects of mechanization are presented here without any attempt to marshal the evidence bearing upon the validity of their implications. An adequate treatment would require a complete analysis of our economic and social system.[58] But it seems pertinent to cite these problems as part of the considerations to be weighed in any judgment upon the aggregate effects of the increasing resort to machines.

[58] For stimulating discussions of many of the economic and cultural aspects of the increasing mechanization of industry see: C. A. Beard, ed., *Toward Civilization;* Stuart Chase, *Men and Machines;* H. S. Dennison, Some Economic and Social Accompaniments of the Mechanization of Industry; E. Mayo, The Human Effect of Mechanization, and E. G. Nourse, Some Economic and Social Accompaniments of the Mechanization of Agriculture, in *American Economic Review, Supplement,* March 1930; and Glenn Frank, *Thunder and Dawn.*