Work Simplification in Ceramics

"WE practically wear the pottery out dragging it through the shop," stated the factory manager of the Hillmont plant of Gladstone Ceramics Company* in summarizing the manufacturing problems of producing pottery and china in a plant which was not originally intended for this purpose. This frank and critical attitude with which the factory operating man viewed his own work was reflected throughout the entire organization, including top managers, and led the company to the recognition of two facts: *first*, that present methods, although they had been improved from year to year, were not and would never be satisfactory unless improvements were taking place rapidly, and *second*, that ideas and principles developed in other plants and in other industries could be applied to the manufacture of ceramics.

It was with this approach that the officials of Gladstone Ceramics Company turned to the Industrial Relations Section of the California Institute of Technology with the suggestion that a project of mutual benefit be developed from a study of their problem of plant layout and manufacturing methods. It is now possible to review the developments from the perspective of a year of work since the project was undertaken in the spring of 1943, and to describe the problem and its partial solution as a case study in the cooperation of the California Institute with

*Fictitious name and location are used throughout for the protection of the company.

A Case Study in Cooperation between the California Institute of Technology and the Ceramics Industry

By VICTOR V. VEYSEY

industry in the field of production engineering, including plant layout and improvement of methods.

To summarize the results gained in the year's contact calls for mention of specific contributions, such as a revision of the layout to eliminate several handlings of materials and to effect a saving as high as 50 per cent in material transportation in the plant while developing flexibility of operation; the simplification of a difficult problem of handling materials in the production of cast ware where the installation of a circulating system was the obvious answer; and minor improvements in operations for forming and decorating pottery and china where a slight saving on each operation may be multiplied by the millions of repetitions of the cycle to show substantial annual economies. Not the least important was the development of principles and approaches, outlined in this article, which are applicable in most industry today.

FROM THE POTTER'S WHEEL

The manufacture of ceramics is one of the most primitive arts. Much of the production of pottery and china still depends upon the simple principle of the potter's wheel. This is particularly true of the ceramic plants in southern California where the emphasis has been placed on the production of highly styled ware, and on the introduction of a certain peasant quality in the ware by the use of much handwork. The Gladstone Ceramics Company has pioneered in styling and in hand production and decorating methods. There was no thought of producing pottery on a mass production, mechanized basis.

Wall tile, fire brick, and sewer pipe, all construction items, had been the products produced at the Hillmont plant prior to 1934. In that year it was decided to supplement the line with pottery and art ware in order to use plant capacity which was idle because of the general decrease in construction. The pottery line received popular acceptance and the space devoted to its production was gradually increased as new patterns were added. Although good sales outlets were established through higher class stores, the pottery line was still viewed as a fad, and tile was looked upon as the major product; hence the pottery layout was treated as temporary.

In 1940 a line of china was added on a pilot plant basis. Since then the major problems of producing a good quality china have been mastered.

The war brought curtailment in the construction industry and major attention was turned again to the production of pottery, art ware, and china. The sale of these items was stimulated because retail outlets were seeking lines which did not require metals or other

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UPPER:—The first process in jiggering is completed by the "batter out" preparing the clay sheet. LOWER:—A tender brings up and removes the molds.

scarce materials. The problem became that of stepping up pottery and china production to meet the new demand, maintaining the handcraft tradition in spite of wartime labor shortages, and using idle capacity in the tile department without certainty as to when the large-scale manufacture of tile would be resumed.

PRODUCTION METHODS

The production of china and that of pottery are similar as to the sequence of operations employed; the most important differences are in the nature of the materials used and in the care employed in finishing and decorating. Also, china is fired a number of times: in the bisque or unglazed condition, after glazing, and after each color is added in decorating, sometimes a total of five or more times. In contrast, pottery as produced in this plant is fired only once after all decoration has been applied.

Pottery and china may be divided into two groups of products: *first,* flat ware, including plates and platters of all sizes, saucers, and shallow bowls; and *second,* hollow ware, including cups, deep bowls, and pitchers. Flat ware is best produced by the jiggering method, which is a modification of the potter's wheel. A plaster of Paris mold is rotated on a horizontal table, and against this mold a thin sheet of clay in the correct plastic state is pressed to form the inner surface of the plate in an inverted position. The outer surface is formed by holding a template to the rotating clay. After forming and trimming, the plate, still on the mold, is dried in an oven. Great skill is required in jiggering, but considerable speed can be developed by a two- or three-man team: one "batter-out" preparing the clay sheet, one jigger man, and one tender bringing up and removing the molds. Elliptical platters are jiggered on a special table with an eccentric motion.

Hollow ware is produced by the casting method. For this purpose a thick solution of clay in water is poured into a plaster of Paris mold having the shape of the outside of the vessel. Water from the clay solution or slip is absorbed by the mold, and a thin layer of clay is deposited against the mold. At the proper time the remaining liquid is poured out. After further drying, the mold can be removed and re-used. Very careful adjustment of the water content of the slip is required for good results; although the slip may be poured, its water content is about the same as that of the plastic clay used for jiggering. This fluidity is accomplished by the carefully controlled addition of certain chemicals.

APPROACHING THE PROBLEM

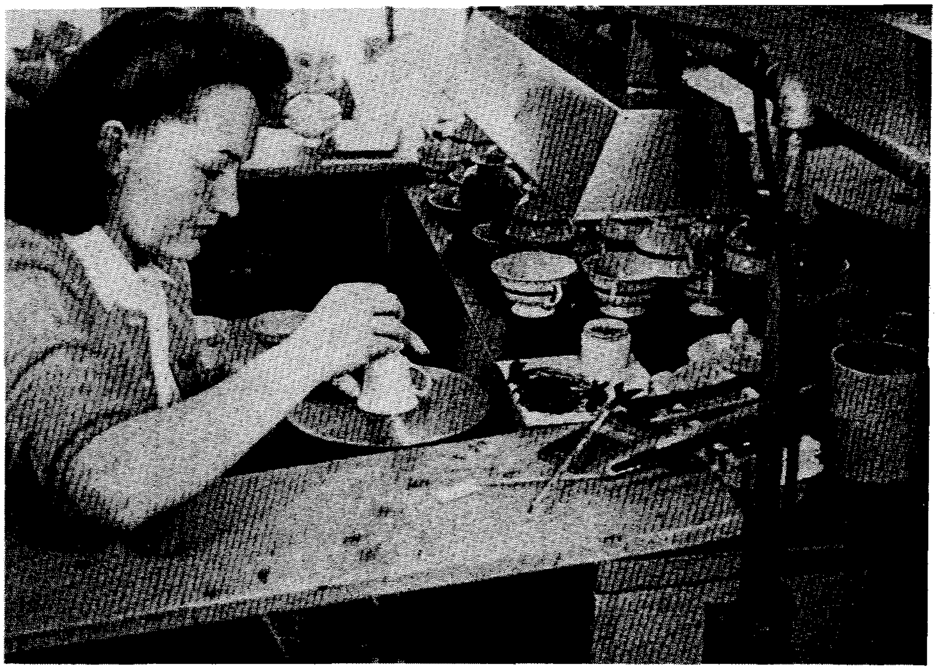
The problem laid before the Industrial Relations Section was twofold: *first,* the development of a revised layout for the expanded pottery and china departments, and *second,* the improvement of methods of performing the operations and handling of the materials to reduce labor.

Company officials offered to open the doors of the plant any time, night or day, for Caltech students to familiarize themselves with the problem. They offered to explain operations to the classes and to examine and criticize the finished reports on improvements. At the same time they agreed to use ideas which to them seemed meritorious, although they of course did not pledge themselves to install any given recommendation. Their own competent engineers were engaged in solving the problems at the same time.

The first step in approaching the problem was to obtain complete data. Inasmuch as the bulk of the work on the project would be done by students in courses in plant layout and in methods improvement given at the Institute, it was desirable to record information on the problem in such form that it could be presented readily in laboratory. For this reason it was decided to cover all of the major operations in the plant by means of motion pictures taken with a constant speed, spring wound, amateur 16 mm. motion picture camera. The films could then be studied and analyzed conveniently in the laboratory without unduly stretching the hospitality of the company officials. The motion pictures were supplemented with a large number of still pictures to give details of layout, plant construction, and equipment. Additional data were provided on present and planned capacity, distribution of the product among several lines, and on dimensions and layout of the plant.

Flat ware is produced by the jigger method, a modification of the potter's wheel.

The bulk of the photographic work was performed by a class of mechanical engineers, seniors at the Institute, who had requested and were given a special course in industrial management with emphasis on motion- and time-study work. It was with some fear that a group of energetic seniors was turned loose with expensive photographic equipment in a pottery plant full of fragile material, but the results were a very pleasant surprise. Far from the "bull in the china shop" outcome which was feared, the men turned in a workmanlike performance, obtained the necessary data with dispatch, and succeeded in producing an edited film of something over 1,200 feet in length which contained more material than could have been recorded in volumes of writing or could have been observed by classes in many field trips. Much of the success of the photographic undertaking was due to the fine cooperation of the company employees. They were not only willing but eager to serve as subjects for the camera. The basic data on this problem have since served with increasing satisfaction as a major problem in four separate courses in plant layout and methods improvement in the Engineering, Science, and Manage-



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Finishing, inspecting, decorating, and glazing operations are similar for all types of ware. Continuous kilns of the type employed for firing tile are used for firing all pottery and china.

ment War Training (E. S. M. W. T.) night school program.

In the course of the work in the plant while taking the motion pictures, a number of facts became evident:

1. Transportation of material in process was excessively lengthy and was sometimes performed the hard way.

2. There was adequate capacity in the plant building for considerable expansion if space were used economically. A number of kilns and other equipment suitable for the manufacture of pottery were idle because of the shortage of orders in tile.

3. The buildings were generally suitable for the uses required. Certain difficulties were encountered because the plant had grown by a series of accretions to an original warehouse structure, but good clear space could be obtained for well-developed lines of flow.

4. Production methods varied throughout the plant from almost primitive methods involving considerable laborious routine work by skilled operators to beautifully mechanized installations for some of the operations.

5. Although there was more than normal latitude provided in rearranging facilities for this layout, certain definite limitations were placed on the problem, due to the importance of flexibility in the plant operations.

Two separate problems had been presented, one, the improvement of the layout and, the second, the improvement of methods in performing the operations, but the two problems were not independent. They would have to be approached simultaneously in the development of new production methods for the company.

PLANNING THE LAYOUT

The problems of methods improvement and the preparation of a layout were divided into the following portions for study by student groups: production of pottery by jiggering method, production of pottery by casting method, production of china by jiggering method, and production of china by casting method. Considerable cooperation was necessary among the several groups because developments and improvements of one group might seriously affect the work of another.

The first step in the procedure was the development of a process flow chart, which is a simple chart showing by means of symbols and abbreviated explanations the sequence of operations, transportations, storages, and inspections which is necessary in the production of the product. In this case four different but related process flow charts were developed, one each for the two methods of pottery manufacture and for the two methods of china manufacture. The drafting of a process flow chart is in itself no contribution to the improvement of methods or of layout, but it has been found both in this case and in industry in general that a complete and definite knowledge of the sequence of operations in performing the work is essential before soundly conceived improvement can be undertaken. It is folly to attempt changes in layout without basing them on thoroughly planned improvement of the flow of work.

Many seasoned production men are inclined to think in terms of an ideal or desired sequence of operations—what is supposed to happen rather than what actually is done. A graphical presentation of performance as given in the process flow chart may reveal the defects in their own operations. The process flow chart serves in three ways:

1. It indicates that the problem of flow of work is critical by bringing defects to light.

2. It facilitates an orderly planning of work and the logical elimination, combination, and improvement of operations.

3. The comparison of an original process flow chart with a process flow chart after the improvements have been made is striking evidence of the worth of the changes.

In this case the development of the process flow chart brought to immediate focus some of the problems in layout. A tabulation of the transportation distances and transportation methods indicated that the factory manager's facetious comment about "wearing the pottery out by transporting it" was not to be taken lightly. The total material handling distance for each group of products was discouraging.

It was further evident from the process flow chart that delays and storages of the material were more numerous than required, leading to the storage in the plant of a very large amount of semi-finished material. This practice was excessively wasteful of floor space, although it had not created any problem in operation, because sufficient space was available for all needs. It did involve, however, a heavy investment in unfinished goods, it tended to cause transportation between operations to be long and to be broken into a series of moves rather than one or two moves, and it was conducive to careless practice in scheduling, production control, and plant housekeeping.

MACHINE CAPACITY

The second step in preparation of the layout was a calculation of required machine capacity to produce the necessary volume of finished material. Furthermore, the capacity of equipment to handle the various operations was balanced so that excessive under-capacity and excessive over-capacity at any point in the flow were avoided. Any computation of machine capacity must be based on some assumption as to the desired volume of production; this assumption depends on business rather than engineering considerations. The uncertainty of the data on the businessman's side of the problem was distressing to engineers who reasoned that they could furnish an economical layout for any given requirement in volume of production but that they must have some guarantee as to what that volume would be. The changeable character of business, on the other hand, made it impossible to guarantee what the volume of production would be next month or next year or how it might be distributed among the several items produced. The businessman desired flexibility to handle the changing situations.

After some study of sales records and due consideration of future possibilities, it was decided to provide capacity for the production of about 30,000 pieces per day in pottery and 8,000 to 10,000 pieces per day in china, at the same time allocating a number of kilns to the production of tile. The estimated distribution of product between cast ware and jiggered ware was: pottery, 35 per cent cast, 65 per cent jiggered; china, 50 per cent cast, 50 per cent jiggered. Machine capacity for each operation was calculated from this assumption. At the same time the future reliability of these estimates was doubtful, so that, although the layout could be designed for this normal output, it was necessary to develop extreme flexibility in the layout even at the expense of efficient operations in order to meet anticipated large swings in volume of business. The major question in developing the layout then became: How can the best compromise be made between efficiency and flexibility?

The third phase of planning the layout was blocking out the required floor space. As it developed in this case the requirements of floor space were not critical, inasmuch as there was idle plant available. Good clear space and a long straight line of flow could be obtained by starting the production of all products at the east end of the plant, where the material could be fed from a spur track which already existed, and by using the full length of all the plant buildings, completing the finished product at the extreme west end of the building and transferring it to the basement for storage and packaging. All important portions of the layout would in this way be located on one floor in a single building and a smooth movement of materials could be accomplished.

At this point a major decision was made. It became evident that an economical type of layout could be achieved by use of the straight line or product type of flow wherein there would be little confusion, back-tracking, or unnecessary handling of pottery, china, or tile as it moved through the plant. At the same time extreme flexibility could be achieved by incorporating many elements of a functional grouping of equipment in the layout, *e.g.*, aligning all kilns for pottery, china, or tile together so that capacity could be swung to one product or the other without moving kilns and without excessive materials handling. This could be accomplished because the processes and equipment used in pottery manufacture, china manufacture, and to some extent tile manufacture were interchangeable. One feature of the existing plant seemed to interfere with this plan: A group of executive offices had been established within the rectangle of plant which would be needed for the layout, producing a narrow point in the flow at precisely the point where the maximum width was needed. The officials agreed, however, that it might be cheaper to build a new office building than to interrupt the flow of the plan.

PLANNING PRODUCTION CENTERS

The fourth step in preparing the layout was that of planning the production centers used in the manufacture of each type of product. By a production center is meant a self-contained unit consisting of a machine and accessory equipment in the work area, working space for an operator or operators tending the machine, space for the movement of materials to and away from the machine, and space for servicing the equipment. A self-contained production center once planned and laid out to scale can be picked up and moved about readily in the reshuffle of facilities which is necessary in planning the complete layout. The production centers were drawn to a convenient scale matching a large floor plan of the

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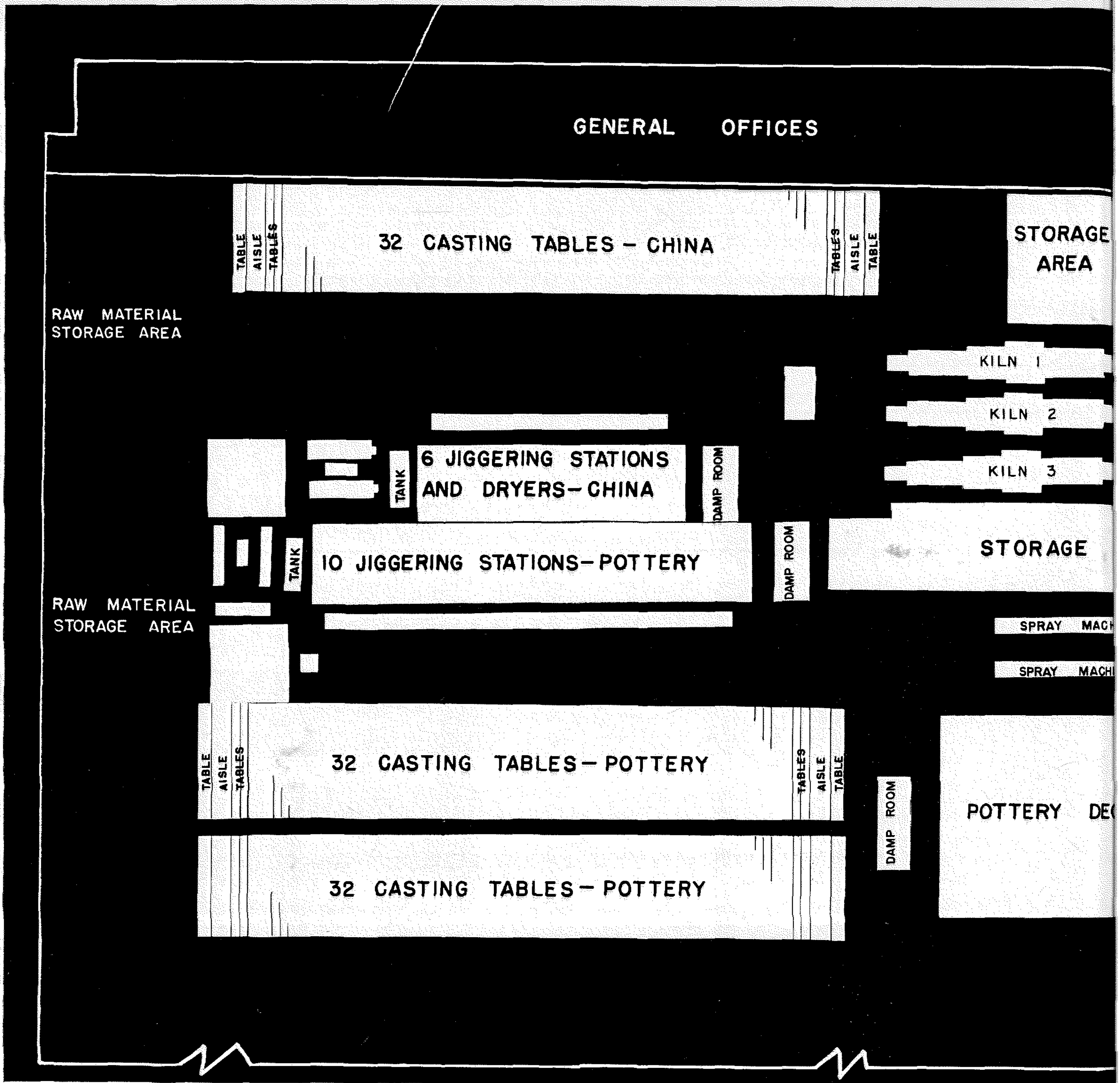
Hollow ware is produced by the casting method. This view shows the plaster of Paris molds for medium-sized bowls.

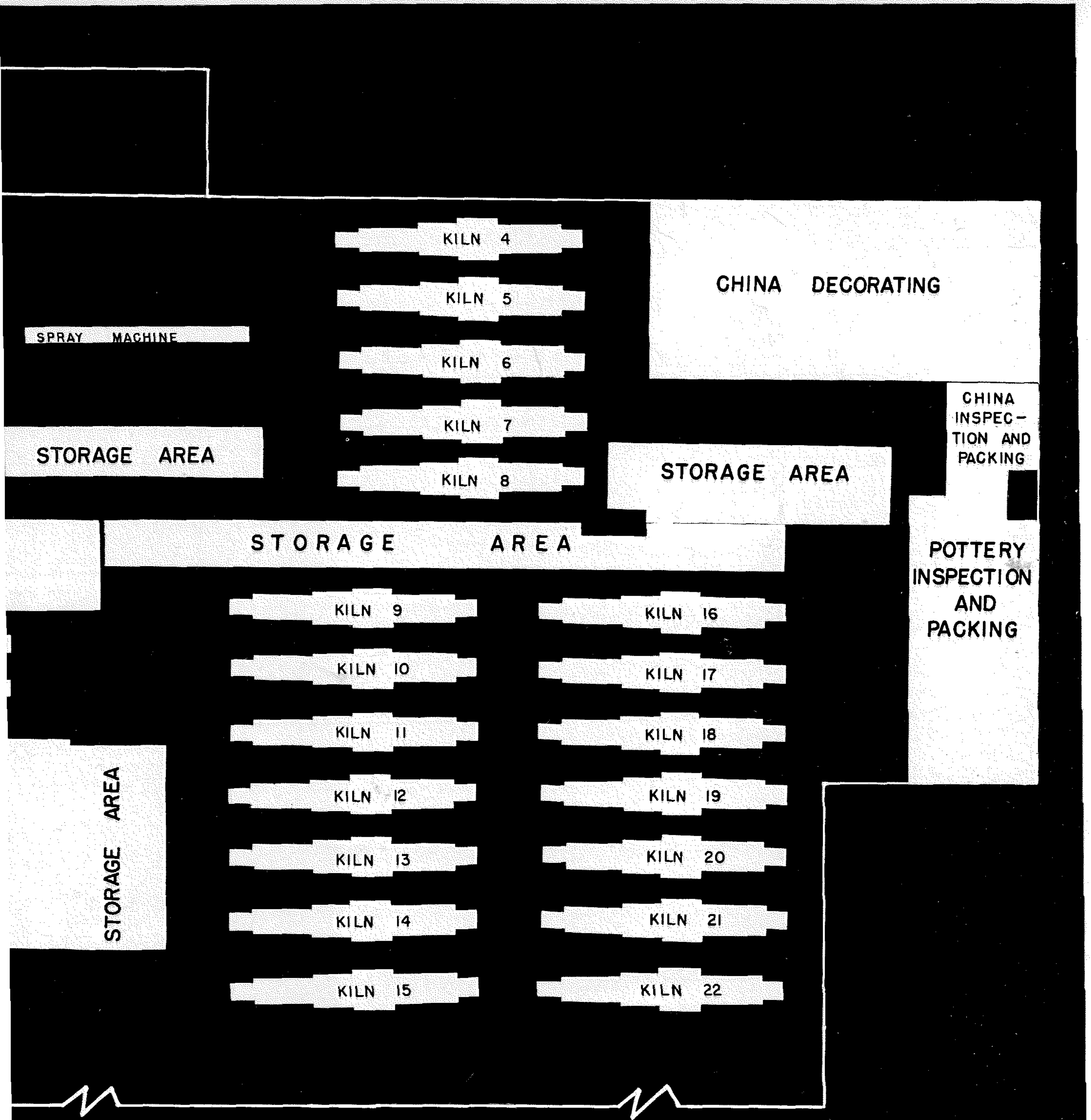


Partially completed plant layout on student layout board. W

plant and were cut out of cardboard for easy handling.

The fifth step was the essential one of arranging the templates of the production centers on the floor plan to produce a layout. A statement of the step is very simple, but the actual development of a layout in this manner is complex because of the infinite possibilities presented. Every arrangement has advantages and disadvantages which must be weighed in appraising its effectiveness. It is a safe statement that if one worked long enough on the problem of arranging the templates he would produce a layout which is better than any he had previously developed. It must be remembered that all practical solutions to the problem will be only successive approximations approaching the ideal of the "one best way." Although this stage of the process is laborious, it is also profitable. The work is greatly facilitated by the use of the cardboard templates of production centers. It is during this phase of the arrangement of the paper cutouts on the floor plan that minor adjustments may be made both in production centers and in the floor space area to be used. The close association of method and layout requires that adjustments be made in the one to accommodate the other.

The sixth step in preparing the layout was selecting a final arrangement of the templates which best satisfied the requirements. The templates were pinned or pasted



ard templates facilitate improvement of the layout.

in place to produce a working layout. Lines of flow tracing the movement of material from one center to the next were drawn in or outlined with colored thread. The development of these lines of flow was a good check on the layout because it brought to light certain difficult or confused situations indicated by unusually long lines of flow, back-tracking of lines of flow, or the intersection of the lines.

At this point a process flow chart of the improved method of performing the work was drawn and new material-handling distances were tabulated. In this way the exact amount of the improvement in the layout was shown and the quality of the layout from the materials-handling viewpoint was demonstrated. Some of the arrangements developed as solutions to this problem resulted in the elimination of more than 50 per cent of the materials-handling distance in the case of pottery manufacture and an even greater improvement in the case of china.

The seventh and final step in developing the layout was to detail and draw up the layout in good form for blueprinting. This involved drawing in of accessory facilities such as service facilities, auxiliary departments, aisle space, locker room and toilets for employees, and other necessary appurtenances to the actual production process. While the major decisions on layout had been

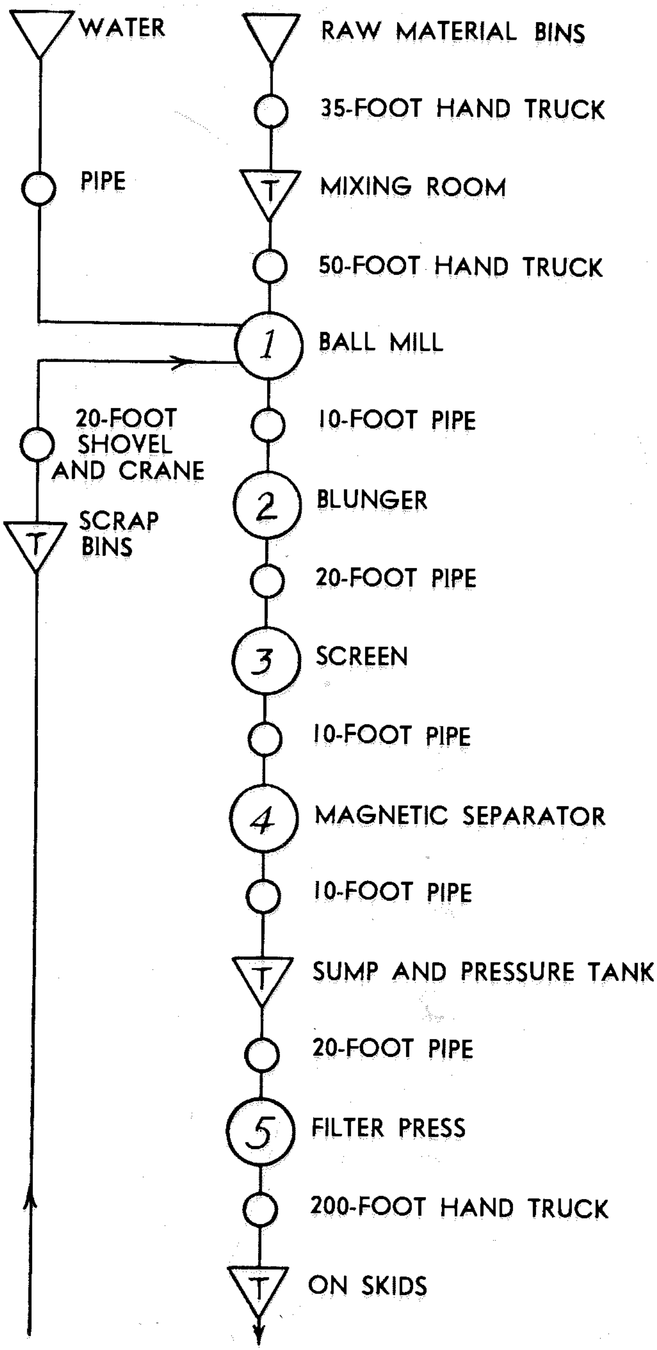


Diagram showing portion of process flow chart for the manufacture of pottery by the jiggering method.

made at this point, it was none the less important to use care in arranging for the details. The quality of the layout may be judged to a considerable extent by its polish and refinement in detail—the hallmark of the competent production engineer. Careful completion of a final report and drawings was required.

METHODS IMPROVEMENT

The problem of the improvement of methods in the individual production centers was considered constantly as the layout was being developed. Some of the suggestions for improvement of methods involved re-engineering of equipment, some involved regrouping of men to operate more effectively, and some involved the use of a new pattern of motions in performing the work. It was in the development of new methods that the motion pictures of operations taken in the plant were of maximum usefulness; more detail could be determined about operations by a careful scrutiny of the motion pictures than could be determined even by prolonged observation of the work in the shop. This was true for three reasons: The motion picture focused the attention of the observer on the method itself and excluded other distracting circumstances; the film could be studied in slow motion or frame by frame if necessary to discover exactly how the operation was being performed; and one representative cycle of an operation could be formed into a loop which could be continuously projected, thereby providing a moving picture of the unchanging method for observation.

The approach in developing new methods was first to select the operations wherein improvement could be expected to have economic significance—that is, those operations involving large amounts of operator-paced time on repetitive performance. Operations such as jiggering, casting, finishing, and inspecting of pottery and china were of this sort, since a number of operators were employed on these jobs and the cycles were repeated millions of times in the course of a year. The second step was the preparation of a process flow chart of the detailed sequence of elements followed by the workman in performing the operation. Such a chart is analogous to the larger process flow charts developed for the complete plant, but for this use it is more detailed and confined to a single operation. The third step was a careful analysis of the film in a hand-cranked projector to develop a man-and-machine chart showing against a time scale the activities of the operator and of his various pieces of equipment during the cycle, or a simultaneous motion chart depicting against time the detailed movements of the operator in performing the cycle. By counting the frames required for the performance of a cycle, it was possible to ascertain with good precision a time standard on the job. This was checked against the standard of performance in use by the company for purposes of scheduling and of wage payment.

The next step was the redesign of the work cycle by applying the principles of motion economy to the design of the work place, design of tools and equipment, and to the use of the human body in most effectively performing the work. As in all engineering problems, the engineering of a new method depends heavily on the ingenuity of the man making the design. He has certain rules and principles to follow but his application of those rules is all-important. Certain of the student groups suggested and developed new methods which were clearly improvements. These improvements were not stumbled upon or arrived at intuitively but were developed by careful application of a logical approach to the problem. In order to make the situation as realistic as possible, students were encouraged to estimate a time standard on any improvement which they suggested and to determine the dollars-and-cents saving in a year of operation, testing its practicality as an improvement against the expense of its installation. This demonstration was disillusioning in some cases and gratifying in many.

THE RESULTS

It is difficult to appraise the effectiveness of a project of this type because it is impossible to determine the increment of progress added by the California Institute's participation to what the company would have made in any event. In some cases the suggestions developed at Caltech were new; in other cases they merely supported

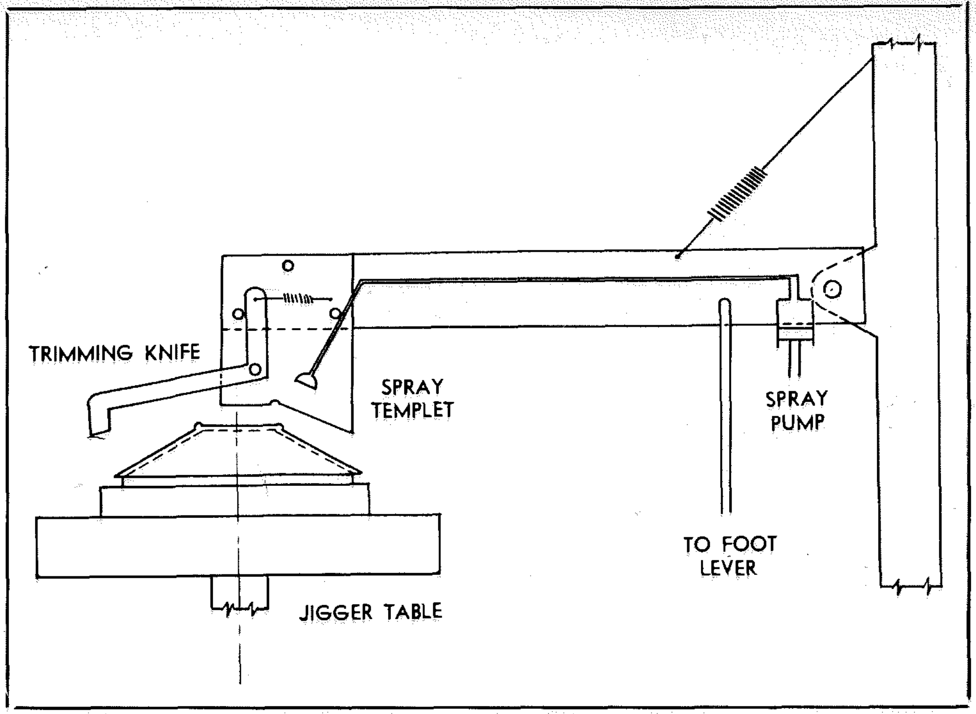


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Diagram showing proposed jigger arm assembly.

conclusions already determined by the company. Many suggestions needed much practical refinement before they were ready for the test of application.

Several specific contributions can be listed as representative of the important items:

1. In layout, the idea of combining the efficiency of straight product- or line-flow of materials with the cross-cutting flexibility of functional grouping of major units possesses great merit in this case. While the idea is not new, it has had only limited application; this is a case where it would be applicable.

2. Revision of the layouts achieved over 50 per cent saving in transportation distance, with several handlings of materials eliminated, combined, or simplified. Since materials were heavy or fragile, this was an important saving.

3. Suggestions for the improvement of the jiggering operation varied from designs for new dryers with automatic loading and return systems to suggestions for the combination of applying water to the revolving vessel and trimming it with the action of the template arm.

4. Numerous suggestions for improvement of the laborious hand pouring operation in the casting department centered around pumping the slip to the casting stations. Despite protests that "it can't be done," a fine circulating system is now operating in the plant.

The company engineers and operating men have taken a very broad gauge attitude about accepting the suggestions rather than resenting them as criticisms.

From the view of the California Institute, this problem permitted the development of excellent material for teaching and made for good training in practical problems for the students with an interest in production problems.

The fact that the California Institute, without a separate department of industrial engineering, should be called on to participate in this undertaking to the mutual benefit of both parties indicates the need for specialized training, research, and service in production engineering in the growing industrial community of southern California. Neither industry nor the California Institute will ignore the possibilities of further collaboration on production problems.

Ceramic Gauges

(Continued from Page 7)

the face of severe priority restrictions on critical steel tools the metal-working industry is still hesitating to adopt the newer ceramic materials. The ceramic industry should not be expected to be the one to promote the use of ceramic gauges, because the volume of material involved represents an insignificant percentage of its total product. It has, however, carried on research to increase the mechanical shock resistance of its materials and has been able to present finished surfaces which are "nonfreezing," "nongalling," and capable of resisting the abrasion of anodized and other finishes found on the pieces to be gauged. The gauge industry is inherently conservative, but there seems to be much of future interest in the nonmetallic standard of measurement.

APRIL ISSUE COVER

The April issue of *Engineering and Science Monthly* featured an interesting view on the cover and several readers of the magazine have requested identification of the subject matter. The caption to the illustration reads as follows: "*Birth of a Multiple Contact Plug:* The electric circuit comes into its own in the multiple contact plug. These connectors are specially designed to meet specific and often unusual requirements. Engineers of the Cannon Electric Development Company have designed and manufactured connectors carrying well over a hundred circuits."