# A PROCEDURE FOR FORECASTING THE MAN-HOURS REQUIRED TO PREPARE PLANS FOR THE CONSTRUCTION OF A PUBLIC SCHOOL

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## PREFACE

Industrial engineers have historically been concerned with determining the most efficient use of men, money, and materials. Until recently, their efforts have largely been confined to industry. The productivity of workers in manufacturing has increased many times through the efforts of industrial engineers and specialists from other disciplines. The output per agricultural worker has likewise increased through a combination of improved seed, fertilizer, equipment and other factors. Although productivity in agriculture and the production of goods has shown a consistent pattern of increase the service industries have been largely untouched by the productivity revolution. At the same time, the number of people required by the service industries has increased and today there are more workers engaged in service than manufacturing. The service industries consequently represent the last frontier for the productivity revolution and, thus, should be of prime concern to industrial engineers.

This paper will deal with only one area of interest: architectural service. Or more specifically, the service of preparing the plans and specifications necessary for construction. This special service, required for practically all construction projects, has remained virtually unchanged from an operational standpoint. Minor improvements have been made in such mechanical items as blueprints, new structural systems and materials but there has been no significant improvement in the basic process of controlling the conversion of a design concept into the tangible plans and specifications necessary for construction.

The reasons for such stagnation in productivity are multitudinous but the fundamental cause may be expressed succinctly as the antithesis of why operations research is so successful. Operations research has an inherent advantage insofar as it requires the contributions from an interdisciplinary team. The service industries, as a general rule, restrict themselves to attracting or training people specialized in the requirements of their particular service and, consequently, do not benefit from the contributions possible from other areas of specialization. This situation portends a significant opportunity and a concomitant problem for industrial engineers and the service industries. Significant increases in service productivity may be obtained through the applications of techniques and procedures already applied to industry. However, before a real revolution is possible, either industrial engineers must become intimately familiar with many diverse forms of service; or personnel responsible for the management and direction of service organizations must acquaint themselves with the basic philosophy of industrial engineering.

Appreciation is expressed to Professor E. J. Ferguson, for his guidance and advice in the preparation of this paper, and to Ed Hudgins, Vice President of Hudgins, Thompson, Ball and Associates, Architects and Engineers, for the permission to study the records, account ledgers, and other data necessary to conduct this investigation.

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## CHAPTER I

## OBJECTIVES

The objectives of this study were actually a series of objectives that were redefined and converged as the investigation progressed. The initial objective that provided the motivating force necessary to conduct the study was merely a desire to apply the basic philosophy of industrial engineering to a service industry. This desire was whetted by observing the wide variations in the profit margins accrued by assorted architectural projects. The objective converged into finding assignable causes for varying profits. In order to accomplish this, it would be necessary to thoroughly understand the process of preparing plans and specifications and the factors that influence or determine the income and expense associated with each project. Merely finding assignable causes, however valuable as this information may be, is only a subobjective. The prime goal must be the discernment of some system that would enable the impact of the assignable causes on man-hours to be predicted and controlled; not merely a roster of reasons why the architectural costs and consequent profit margins are so varigated. Naturally, the system devised would be restricted in its application to the organization being studied. However, it may be possible to present general conditions and basic relationships that would be useful to all architects-engineers. In any case, the fundamental philosophies and investigative procedures developed in conducting the study would serve as a guide for other organizations engaged in providing similar service. Such organizations would not have to start at the same rudimentary level. The study would provide a valuable guide for these other organizations to conduct their own analysis and devise a system for controlling internal costs based on the nuances of their own operations.

To recapitulate, the objectives may be formally summarized as follows:

1. To investigate the basic nature of the internal operations required to provide architectural service.
2. Establish the basic factors influencing the direct cost incurred in providing architectural service.
3. Provide an investigative procedure by example that will aid organizations engaged in providing architectural service in conducting their own analysis and establishing a cost control system based on the detailed characteristics unique to their own operations.

## Conclusions

The objectives of the study were attained. The fundamental nature of the internal operations required to render architectural service were studied in detail and the various factors influencing their costs were reported. An example system was devised, based on data peculiar to the host architect, that could be used to predetermine man-hour requirements and, thus, control to some extent the internal costs required to provide architectural service. At the same time, the fundamental relationships and the investigative procedures developed in the study will guide other organizations engaged in providing architectural service in conducting their own analysis and developing a cost control system based on their own operations.

Certain aspects of architectural service, such as the preparation of specifications, are ripe for the productivity revolution. Data processing equipment could easily be used to store, assemble, and print out in reproducible form the various combinations of standard statements that together make a set of specifications.

Other areas will require much more investigation. The most significant possibility is the ability to actually establish a production schedule for the simultaneous preparation of plans and specifications for multiple projects. In any event, developing and implementing the productivity revolution will require the closest possible cost scrutiny. As presented in the study, architects operate on almost a fixed income basis and reducing internal costs is not necessarily an advantage unless the quality of the service is not reduced. The total costs, including such intangibles as service quality, client goodwill, and the costs associated with developing and maintaining a cost control system, must be considered. The selling price of service is not subject to the architects control and the benefits of increase profit via lower internal costs could well be exceeded by the burdens and other costs necessary to obtain the associated benefits.

## CHAPTER II

## THE GENERAL NATURE OF ARCHITECTURAL SERVICE

Architectural service is an undifferentiated service from the standpoint of its cost to the client. All architects within a given area adhere to the same fee schedule. The fee is usually expressed as a fixed percentage of the construction cost which makes it virtually impossible for a prospective client to predetermine any difference between architects with respect to the cost of architectural service. An architectural firm will consequently attempt to create a differential relative to the value the client will ascribe to the service by establishing a reputation of providing better architectural service for the same fee. The philosophy of doing more, and doing it better, for the same fee increases the cost of the plans and specifications and, consequently, reduces profit margins.

Doing more for the same fee also means that various specialist must be kept available to meet the varigated demands imposed by the diverse projects requiring architectural service. Specialization invariably results in a reduction in the percent of time such personnel may be profitably utilized with a corresponding increase in the overhead of the organization rendering the service. All successful organizations expand and adding more specialists means ever increasing allowances for overhead. As the size of the organization expands the fee required to recoup the cost of providing architectural service also increases.

Since the fee is a fixed percentage of construction cost, the architect soon discovers there is an obvious minimum size or project cost that can absorb the total cost of rendering the architectural service. Nevertheless, the architect cannot afford to refuse projects merely because he will lose money. Naturally, such marginal projects will not be encouraged, much less solicited. But, if a prospect marginal client makes a direct request for service, the prospect becomes a client and the service will be provided. The architect cannot afford to do otherwise. Establishing a reputation for refusing projects would invariably result in fewer architectural clients of all size categories. Also, the losses incurred on small projects may be used as filler projects to be worked on in otherwise idle time. Filling in the valleys of a work schedule for large projects will reduce the overhead allowance and, thus, lower the breakeven point. Small projects can also be construed as a promotional expense. For instance, the architect cannot realistically refuse a contract for a small four classroom school addition merely because he will lose money on the project. Next year, the same school district may require a large new school that will absorb the loss incurred in designing the small four room addition.

The philosophy of doing more also means that the architect will be more responsive to the client's every request. It is reasonable and proper that the architect conduct a thorough investigation of the project and prepare alternate plans and cost estimates of solving the design problem. However, many clients will capriciously change floor plans, construction materials, and the like after the design has been established and the working drawings are being prepared. Such changes and revisions significantly increase the cost of providing architectural service. The architect can reduce the economic impact of a capricous client through tact and diplomacy, but they cannot always afford to eliminate such cost increases by overt refusal since an architect lives by his reputation of satisfied customers.

Since the fee is determined by a percentage of the construction cost, the exact income is not determined until the project has been completed. However, the anticipated construction cost is determined when the bids are opened and the architect, of course, must have some concept of how much money the client is prepared to spend for the facility before plans are even started. On the other hand, the majority of the architects expenses are incurred in preparation of working drawings. In other words, there is an inherent inverse relationship between the rate the architect consumes the fee and the degree of confidence associated with the estimate of how much the fee will actually be. Contractors will occasionally reduce their profit margins and submit a lower than normal bid during slack periods in order to keep an experienced and skilled construction crew gainfully occupied. They may also bid somewhat lower on prestige projects, on projects having a high probability of repeat business, or they may even make an error in their cost calculations. All of these factors reduce the contract amount and the architects fee.

The architects profit is significantly influenced by two variables, the client and the contractor, over which he has little or no control. Restricitng a client's caprice requires the ultimate in diplomacy and a client that is either indecisive or capricious to any degree will invariably inflate the cost of preparing plans and specifications. Also, regardless of why a contractor will submit a lower than expected bid on a project the affect on the architect, reduced income, remains constant. Finally, there is always the case of having to reject all bids because they exceeded the available funds. The plans must be revised and resubmitted to the contractors in the hope of attracting at least one bid that is within the available money. The fee, however, is always a percentage of the construction cost and usually remains constant no matter how many times the plans are redrawn before receiving and acceptable bid.

Architects are in business in order to render architectural service. They will not refuse a project; further, they will knowingly do many things that reduce and occasionally completely eliminate profits. However, it is fundamental that profit is necessary in order to continue offering the service. With limited control on clients caprice and no control over the contractors bid, architects must consequently concentrate on reducing their own internal costs in order to maintain adequate profit margins.

One technique for maintaining cost control is simply subjectively estimating the man-hours required and establishing a deadline for the completion of working drawings. The principals of an architectural organization are astute enough to realize that you cannot give someone a job without saying when you expect it back and experienced enough to estimate the hours required for a single project with relative accuracy. However, if such a judgment may be made intuitively, there should be some means of developing a more objective procedure from the historical data and experience that molded the intuition.

Some architects apply a procedure known as the budget technique for controlling costs. A principal estimates the probable fee and then decides how much should be retained for profit and overhead. The remainder is apportioned over the various specialties in accordance with the principals estimate of their percent contribution to the preparation of plans and specifications. Control is established by comparing the dollars charged by each specialty as the project progresses to the amounts originally forecast. This particular approach may or may not be an improvement depending on the relative accuracy of the original estimate of how much should be spent preparing plans. Obviously, if someone with the deadline technique can estimate the total hours or dollars, they should also be able to apportion the effort over the various specialties required to prepare the plans and specifications.

# CHAPTER III

## DETAILS OF OPERATIONS AT ORGANIZATION BEING STUDIED

All of the data used in this analysis was obtained from the Oklahoma City office of Hudgins, Thompson, Ball and Associates - Architects and Engineers. The firm also has offices in Tulsa, Oklahoma, and Washington, D. C., but the investigation was restricted to those projects prepared by the architects and engineers in the Oklahoma City office.

The data was obtained from two principal sources in the Oklahoma City office: the accounting records and the files describing each project.

The accounting records are based on time sheet which is prepared by each employee every two weeks and sent to the accounting department. Each employee is responsible for recording how many hours were worked and on which projects during the two week period. An example time sheet is included in this chapter (Figure 1). The hours are recorded in accordance with the specialty involved and during which phase of the project the hours were worked.

The duration of an architectural contract is divided into two distinct portions; the design and construction phases. The design portion contains all the effort required to prepare plans and specifications and is concluded with the award of a contract to a contractor. The construction phase of the project consists of approving materials,

## TIME SHEET

Name ____________ Employee No.* ____________ Period Covered ____________ 19__

Address ____________ through ____________ 19__

| Job No. | Description | Stage | | | Classification | | | | | | | | | | Hours Worked | | | | | | | | | | | | | | | | Total | Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Prel. * | Wk. Drwg. | Constr. | Arch. | Str. | Mech. | Elec. | Spec. | Repr. | Surv. | Civil | Supv. | PLANNING *USE CODE NO. | Wed | Thu | Fri | Sat | Sun | Mon | Tue | | Wed | Thu | Fri | Sat | Sun | Mon | Tue | | | |
| | General | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Total | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Earnings: ________ Hrs. Reg. Time

________ Hrs. Overtime

*Added since start of study

Approved by ____________

Figure 1. Time Sheet

checking the contractors performance and progress and in general rendering any service required to ensure successful construction and completion of the project. The division is determined in all cases by the award of a contract; all man-hours expended on the project prior to the contract are charged to the design phase, all hours worked after the award of a contract are a part of the construction phase.

In addition to indicating the phase of the project, the time sheets have the provision for recording the particular specialty or nature of the hours worked. The man-hours are recorded in the following categories: architectural, structural, mechanical, electrical, specifications, reproduction, surveying and civil (engineering).

The architectural portion consists of the time required to develop a design and then to prepare the architectural plans necessary to convert the design into a set of working drawings. The structural category is the time required by the structural engineers to calculate and determined the structural system necessary and then prepare the required structural drawings. The structural engineers are the only engineers that consistently prepare their own drawings. The mechanical and electrical departments both consist of an engineer and one draftsman. The hours charged to these categories reflect the time for the engineer to design the system and the draftsman to prepare the plans. The specification classification receives hours by the chief specification writer, and his assistants, plus the typing time required to prepare the specifications for their respective sections. The man-hours required by the engineers to prepare the mechanical and electrical specifications in draft form is charged to the specifications category. The reproduction classification includes all hours required to print the drawing and specifications. The survey and civil engineering categories contain the hours required to survey the site and make a plot plan and the design and drawing of any required site improvements such as drainage systems or streets. The "supv" column refers to supervision and is limited to the construction phase of each project. Supervision includes the time required to inspect construction, approve materials and progress payments, or any other service required in the clients interest during the construction phase.

The foregoing is only a brief description as to the basic nature of each specialty and summarizes the accounting criteria for charging man-hours to the various specialties. The contents of each category are described in greater detail as the analysis develops.

As mentioned previously, all the man-hour and dollar figures in this analysis were obtained from the accounting record of each studied project. The accounting ledgers obtain their data from the employees through the periodic submission of a time sheet. Each employee is responsible for the accuracy of his time sheet. Consequently, the procedures developed in the course of the investigation are only as accurate as the accuracy of the time sheets supplied by the employees.

The accuracy of these time sheets is somewhat a matter of conjecture. The accounting office is confident of their accuracy but they have no other real alternative procedure of accumulating the data required to maintain the necessary accounts. The time sheets are apparently accurate enough for their prime purpose of accounting records and are probably accurate enough for the purposes of this investigation. However, the time sheets can make no allowances for shifts in productivity of the office in general which could introduce a significant error.

The principals of the organization are aware that everyone must have some idea how long they have to complete their phase of the project. Deadlines are established in accordance with their estimation of how long the preparation of working drawings should take and sub deadlines are established for each specialty. These deadlines are rather loose at moderate work loads but gradually become more constrained as the volume of work going through the office increases. If constrained deadlines are met, the productivity has increased. As more work is funneled through the office, overtime may be required which, depending of course on the amount and duration, will generally reduce productivity. On the other hand, productivity drops during slack periods. An individual may have absolutely nothing to do for hours at a time, however he will never report it as such on his time sheet. Slack hours will probably be apportioned over the various hours worked during the period or charged to the largest job worked on during the period. There seems to be a tendency to let larger projects carry more than their fair share of the hours worked. Apportioning the man-hours over all the projects worked on during the period would inflate the production cost of each job to the same degree and, thus, the difference between specific projects would not be significant. Also, the projects included in the analysis are spaced out over three years of operation so there should be a satisfactory mix of different background work loads.

Logic indicates that the affect of the short term changes in productivity are minimized by the apportioning of man-hours and the subtle long term shifts minimized by the length of the period studied.

However, the exact magnitude of any change in productivity, and its corresponding impact on this analysis, is indeterminate.

## CHAPTER IV

## PRELIMINARY INVESTIGATIONS

It was virtually impossible to predetermine the precise course of the investigation because of the size of the organization being studied and the paucity of available data. The system of recording man-hours and the description of each project that existed when this investigation was launched was never planned; rather, it just evolved. Further, it evolved gradually to solve specific situations with little or no consideration to the fit of each form and file into an over-all scheme. As a result, there is considerable redundancy between reporting forms. Also, there is considerable laxity in completing the files on each project. The necessity of these records for day-to-day operations is graphically demonstrated by the fact that there are numerous completed projects that have not been formally recorded at all. In a project of this size, it is impossible to forecast the impact of a manipulation on a single variable with satisfactory accuracy. Consequently, each manipulation or trial procedure required a complete round trip through the available data.

The initial investigation indicated that the analysis would have to be confined to a single type of architectural contract. Reducing the scope of architectural contracts studied to a single type of construction almost automatically confined the investigation to public school construction projects. Public school construction goes on constantly and, therefore, it is the only type of architectural contract that occurs frequently enough to accumulate the volume of historical data necessary to conduct the investigation. However, eliminating the one of a kind project and concentrating on an almost repetitious type of construction may have a deleterious affect on applying any results developed to other types of construction. On the other hand, there is considerable variety encountered within the school construction category. The difference between single and multi-story schools and those with and without special areas such as cafeterias and gymnasiums plus the alternative structural systems and architectural materials introduces quite a rather wide variety of buildings within the single category of public school construction.

The first cycle through the data considered of a preliminary investigation into twenty of the most recently completed school construction projects. The total number of dollars expended in fulfilling the obligations of an architectural contract (design plus supervision) was obtained from the accounting ledgers of each project. The floor area of each facility was obtained from the records and files on each building and recorded with the total dollars required to fulfill the architectural contract on each facility. The ratio of the total dollars per square foot was calculated as a measure of the total cost required to fulfill the contract in terms of the size of the facility. These ratios were then plotted against the floor area of the facility. The result was a scatter diagram that revealed nothing spectacular but did tend to confirm the almost obvious conclusion that as the size of the project increased, the dollars per square foot required to prepare plans and specifications and supervise construction decreased. In other words, a 30,000 square foot school required more design dollars than a 15,000 square foot school, but not twice as many. The single graph produced in the first phase is sketched in Figure 2.

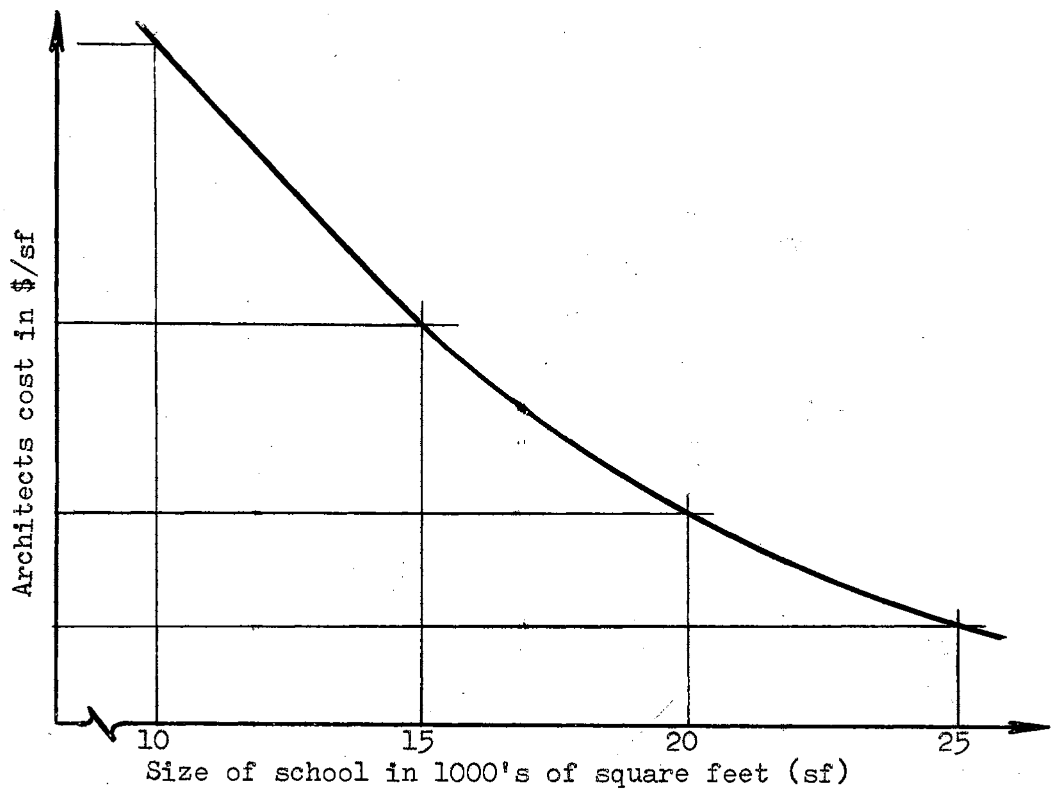



Figure 2. Architects Cost Per Unit Area Versus Area of Schools

The units have been purposely left off the vertical axis because the scattering of the data would not justify anything more refined than a sketch of the general relationship between the size of the facility and the cost incurred in fulfilling all the requirements of an architectural contract. However, the slope of the sketch did indicate that it might be possible to obtain an adequate mathematical expression for the relationship if more data was obtained.

The initial investigation suggested the following approach to the problem. The first step would require obtaining the total development cost on enough projects to ascertain what, if any, mathematical relationship existed between the total cost and the size of the facility. At the same time, the components of the development cost, architectural structural, etc., would be recorded for each project and expressed in terms of a percentage of the total cost. Thus, for future projects, the anticipated total cost could be approximated by entering the estimated size of the facility in square feet into the mathematical expression developed from historical data. The anticipated total cost could then be apportioned over the various specialties in accordance with the historical percentages accumulated from past records. The foregoing appeared to be a reasonable and logical approach to the problem, unfortunately, proving otherwise consumed a prodigious quantity of man-hours.

The previous twenty projects and an additional forty were analyzed in depth to obtain the relationships and expressions necessary to predict the total man-hours required to prepare plans and specifications and supervise construction. The data in Table I represents a typical project and indicates the information obtained in each project.

After the following data was obtained on each project, the above outline was repeated and each entry was expressed as a percent of its respective column total. In addition, the average salary in dollars per hour for each specialty was also calculated. The average per cent cost contribution of each specialty and its corresponding average hourly cost is summarized below in Table II.

TABLE I

DOLLAR AND CORRESPONDING MAN-HOUR CONTRIBUTIONS OF THE VARIOUS SPECIALTIES TOWARDS THE TOTAL COST OF PREPARING PLANS AND SPECIFICATIONS FOR A TYPICAL PROJECT

| | Architects Total Cost | |
|---|---|---|
| | $/1000 SF | hours/1000 SF |
| Architectural | 114.00 | 40.80 |
| Structural | 21.6 | 7.32 |
| Mechanical | 18.0 | 6.31 |
| Electrical | 16.8 | 5.63 |
| Specifications | 12.0 | 4.41 |
| Reproduction | 3.6 | 1.45 |
| Supervision (inspection) | 54.0 | 19.50 |
| TOTAL | 240.0 | 85.42 |

TABLE II

AVERAGE PERCENT COST CONTRIBUTION AND CORRESPONDING PAY RATES OF THE VARIOUS SPECIALTIES TOWARDS THE TOTAL COST OF PREPARING PLANS AND SPECIFICATIONS FOR A TYPICAL PROJECT

| | % cost contribution | average salary $/hr |
|---|---|---|
| Architectural | 44.0 | $3.04 |
| Structural | 9.8 | 2.95 |
| Mechanical | 7.6 | 2.85 |
| Electrical | 7.0 | 2.98 |
| Specifications | 5.0 | 2.71 |
| Reproduction | 1.5 | 2.48 |
| Supervision (inspection) | 25.1 | 2.77 |

The civil engineering category did not occur with sufficient frequency to establish a percent average cost contribution. A description of each facility was compiled from various sources. A copy of the form used to collect and assimilate the data in Tables I and II is included in the Appendix.

The total cost of each project, expressed in dollars per square foot of floor area, was plotted against the size of each facility, a duplication of the approach used in the preliminary investigation. The resulting scatter diagram was considerably more scattered than anticipated. In fact, the reduction in design cost per unit area that was relatively clear on the preliminary plot was barely discernable. The degree of scatter was reduced somewhat by transforming the vertical axis and plotting the total cost to prepare the plans and specifications, including the supervision of construction, against the size of the facility. The resulting plot is presented in Figure 3.

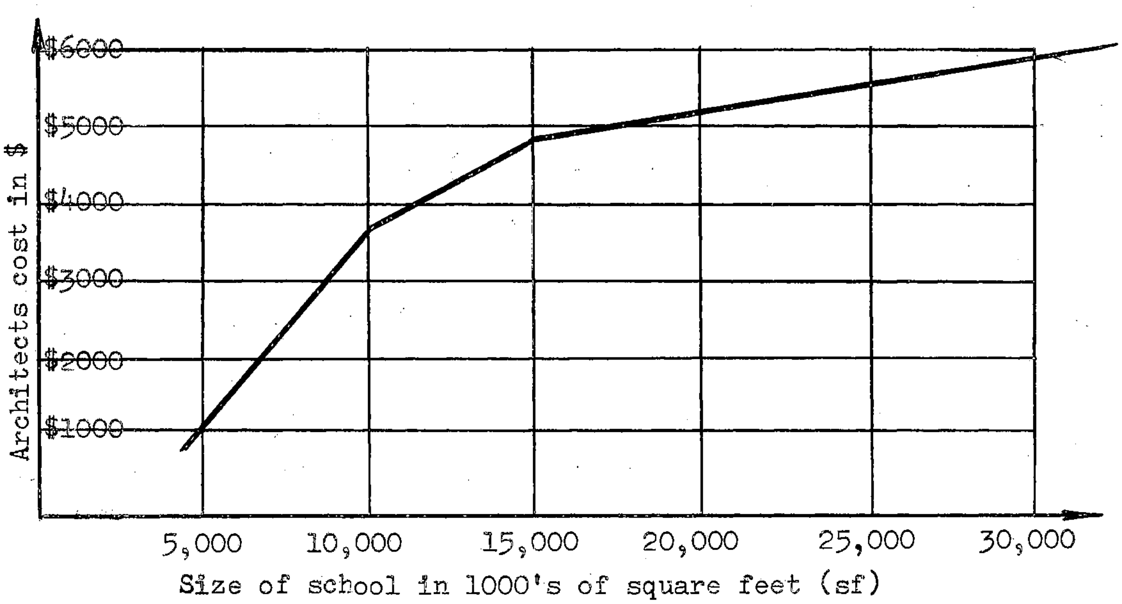



Figure 3. Architects Total Cost Versus Size of School

Transforming the vertical axis did not consolidate the data to the extent necessary to use the average percents developed from historical records. The disparity between the total costs of facilities of comparable size eliminated the possibility of obtaining reasonably accurate predictions from mere averages.

The description of each facility and each facility's deviation from the historical averages were studied in an attempt to find an assignable cause for the deviation. In addition, supervisors of the various specialties were asked the different factors that influenced the time required to prepare plans and specifications. Some of the different systems encountered in the past projects are outlined below in descending order of anticipated difficulty:

Architectural: senior high, junior high, elementary

Structural: multi-story; nonload bearing, load bearing

single story; nonload bearing, load bearing

Mechanical: hot water heating system, gas space heaters.

The descriptions of each project were studied again with the aim of establishing a level of difficulty relative to the historical averages for each type of system. Perhaps a difficulty index could be established whereby a set of difficulty factors could be assembled in accordance with the different systems encountered in a future project. The factors could then be used to adjust the average costs to more closely reflect the difficulty of the project at hand.

The attempt to establish a difficulty index made only slight reductions in the deviations between actual job costs and historical averages. Apparently, there are other factors that significantly affect the cost of preparing plans-specifications and supervising construction. The accounting records were studied, entry-by-entry, and the following conditions were revealed:

(1) The cost of supervision is determined by the quality of the contractor and the duration of the contract. Both of these characteristics are beyond the scope of the architect's control; nevertheless, the service must be rendered in order to fulfill the obligation of the contract. Since neither the architect nor predeterminable characteristics of the building control the cost, it is impossible to predict the cost of providing supervision service. Consequently, further investigation was confined to the portion of the project under direct control of the architect: the design stage.

(2) The projects are generally monitored as they progress through the office by the principal of the organization that made the contact with the client and obtained the signed architectural contract for the facility. Since the analysis is confined to school construction, there is considerable repeat business involved, with the result that two or three principals of the organization have shepherded all of the studied projects through the office. There is nothing wrong with this in itself, but since one principal apportions his time over each job worked and another may charge all his time to overhead, which is apportioned over all jobs, the unfortunate result is an inflationary factor on the cost of projects that are supervised by the principal that charges his

time to each project. Consequently, all charges made by principal of the organization to the projects included in further analysis will be deleted from the cost of preparing plans and specifications.

(3) The architectural category appears to be a catchall for all the hours worked on the project that will not fit another category. For instance, a secretary may type a letter that concerns the subject; this time is charged to architectural. Other miscellaneous charges appear in the architectural account but, since there is no means of determining precisely what was involved, there is no consistent criteria for judging their authenticity so they must remain in the project totals. The cost of surveying is generally charged to the architectural account. However, surveying is charged to civil engineering when the nature of the site requires civil engineering improvements.

The following cycles through the data were confined to the design phase of each project and limited to the following categories: architectural, structural, mechanical, electrical, and specifications. The reproduction and civil engineering classifications have been eliminated. Reproduction is more of an overhead allowance and civil engineering does not occur with sufficient frequency. The next chapter discusses the preparation of specifications and why it was necessary to eliminate this specialty from the study.

# CHAPTER V

## SPECIFICATIONS

A set of specifications, which specify construction materials and procedures, are prepared for each project. These specifications are divided into mechanical, electrical, and architectural portions. The mechanical and electrical sections are prepared by the engineers responsible for the preparation of mechanical and electrical plans. All items not included in these two sections are the responsibility of an architect that has specialized in the preparation of specifications. Thus, the total number of hours charged to the specifications category through the design phase includes mechanical and electrical engineers, the specification writer, and the typing time required to prepare the masters prior to reproduction.

The analysis became deeper as it progressed and concentrated on discerning the factors that influenced the design time of the various specialties. The investigation was now limited to public school construction and the cost of preparing the necessary plans and specifications. The cost of preparing these plans and specifications omits the cost of supervising construction by definition. The costs incurred in the construction phase of architectural service were eliminated from further consideration for reasons discussed in Chapter IV. However, the final phases of the investigation demonstrated that the system developed for predetermining man-hour requirements could not account for the wide variations encountered in studying the cost of specifications. This chapter is somewhat out of context since the data presented here was concurrent with the presentations in the following chapter. However, since the preparation of specifications were eliminated from the final presentation (Chapter VI), it was necessary to discuss the reasons for their elimination prior to Chapter VI.

Table III summarizes the man-hours required to prepare the specifications for the same projects that were included in the final analysis. Presented in Table III are: the man-hours required to prepare specifications expressed in terms of project size, the absolute man-hours, and the absolute man-hours expressed as a percentage of total man-hour requirements in the design phase. Note the wide variations encountered in the three columns of Table III. The man-hours required to prepare the specifications does not relate to either the size of the project or the total man-hour requirements. If the specifications effort were related to the difficulty of the project with respect to the other specialties, there should be at least some consistency in the per cent of total hours required to prepare the specifications.

As mentioned previously, the man-hours required to prepare the specifications includes the time for typing and the time contributed by mechanical and electrical engineers in addition to the time required by the specification writer. Further investigation was directed towards breaking down the total hours required to prepare specifications into its various components. The accounting ledgers were surveyed item-by-item for each project and the charges by mechanical and electrical engineers, specification writers and typists were removed and totaled separately. The breakdown of specification hours is presented

TABLE III

TOTAL MAN-HOURS REQUIRED TO PREPARE SPECIFICATIONS

| Project No. | Hours Per 1000 SF | Hours | Per Cent of Total Hours | |
|---|---|---|---|---|
| 1 | 19.80 | 40 | 15.9 | |
| 2 | 5.60 | 22 | 7.2 | |
| 3 | 7.60 | 30 | 12.8 | |
| 4 | 13.10 | 52 | 12.0 | |
| 5 | 15.00 | 63 | 17.0 | |
| 6 | 4.75 | 20 | 12.5 | |
| 7 | 14.50 | 70 | 12.6 | |
| | 11.50 | 42.4 | 12.8 | Averages for Group 1* |
| 8 | 4.38 | 22 | 9.6 | |
| 9 | 5.80 | 30 | 12.4 | |
| 10 | 6.74 | 35 | 10.3 | |
| 11 | 2.86 | 15 | 9.4 | |
| 12 | 5.20 | 28 | 14.0 | |
| 13 | 7.08 | 39 | 14.5 | |
| 14 | 12.30 | 68 | 14.1 | |
| | 6.34 | 33.8 | 12.0 | Averages for Group 2 |
| 15 | 6.65 | 40 | 7.2 | |
| 16 | 4.78 | 30 | 7.0 | |
| 17 | 8.68 | 60 | 9.1 | |
| 18 | 6.95 | 51 | 10.3 | |
| 19 | 10.10 | 76 | 10.6 | |
| 20 | 1.30 | 10 | 2.4 | |
| | 6.41 | 44.5 | 7.77 | Averages for Group 3 |
| 21 | 1.00 | 8 | 2.6 | |
| 22 | 8.40 | 73 | 14.0 | |
| 23 | 6.40 | 60 | 7.2 | |
| 24 | 6.10 | 58 | 13.6 | |
| 25 | 6.10 | 60 | ** | |
| 26 | 4.50 | 45 | 7.7 | |
| 27 | 6.04 | 64 | ** | |
| 28 | 1.40 | 15 | 3.4 | |
| | 4.98 | 47.9 | 8.08 | Averages for Group 4 |

*Criteria for grouping is by area only and is performed merely to reduce the amount of data handled at a given time (see Chapter VI).

TABLE III (Continued)

| Project No. | Hours Per 1000 SF | Hours | Per Cent of Total Hours | |
|---|---|---|---|---|
| 29 | 7.94 | 88 | 12.9 | |
| 30 | 3.20 | 39 | 6.2 | |
| 31 | 6.75 | 86 | 10.0 | |
| 32 | 2.34 | 30 | 9.2 | |
| 33 | 3.68 | 50 | 10.2 | |
| 34 | 5.45 | 76 | 10.0 | |
| | 4.89 | 61.5 | 9.75 | Average for Group 5 |
| 35 | 4.50 | 68 | ** | |
| 36 | 3.72 | 64 | 6.8 | |
| 37 | 3.35 | 65 | 8.8 | |
| 38 | 6.40 | 128 | 12.2 | |
| 39 | 2.14 | 50 | ** | |
| 40 | 2.50 | 66 | 6.4 | |
| 41 | 4.38 | 128 | 10.0 | |
| 42 | 1.70 | 65 | 4.9 | |
| | 3.59 | 79.2 | 8.18 | Average for Group 6 |

**Portion of project performed by outside consultant. Averages adjusted accordingly.

in Table IV.

All projects require mechanical and electrical specifications. From Table IV, however, it is apparent that not all jobs are charged for the preparation of the mechanical and electrical specifications. The engineers responsible for their preparation relate that no hours are charged to specifications unless the total time required for their preparation exceeds the "usual two or three hours."

Table IV also presents the ratio of the hours charged by the specification writer to the hours charged by the typists. This particular ratio varies by a factor of forty. The typists' time includes correcting mistakes, collating, etc., in addition to the hours actually spent typing the specifications. The specification writer must spend time reviewing plans and consulting with the client and material suppliers before starting the specifications. The draft of the specifications presented to the typist includes long hand copy and preprinted sheets in which paragraphs to be included in the specifications have been checked off.

The specification writers relate that the chief variables affecting the number of hours required to prepare specifications are the client and when the preparation of specifications is started with respect to the per cent complete of the architectural plans. Architects, unfortunately, have little or no actual control over their clients. Every effort is made to pre-determine the project requirements, but if the client changes his mind he has the prerogative to change the plans and specifications to suit his revised desires.

The specification writers assert that the preparation of specifications should not be started until the architectural plans are at least

TABLE IV

BREAKDOWN OF MAN-HOURS REQUIRED TO PREPARE SPECIFICATIONS

| Project No. | * Mech. Spec's | * Elec. Spec's | Remaining Spec Hours (A) Write | (B) Type | (B)/(A) |
|---|---|---|---|---|---|
| 1 | | | 10 | 29.5 | 2.95 |
| 2 | | | 5 | 18.5 | 3.70 |
| 3 | | | 12.5 | 16 | 1.28 |
| 4 | 6 | | 12 | 32.5 | 2.71 |
| 5 | | | 34 | 29 | .85 |
| 6 | 2 | | | 18 | - |
| 7 | 4 | | 41 | 25 | .61 |
| 8 | | | 8 | 14.5 | 1.81 |
| 9 | 2.5 | | 9 | 15.5 | 1.72 |
| 10 | | | 8 | 25.5 | 3.18 |
| 11 | | | 6 | 9 | 1.50 |
| 12 | | | 10 | 17.5 | 1.75 |
| 13 | 2.5 | | 19 | 17.5 | .92 |
| 14 | | | 43 | 25.5 | .59 |
| 15 | 11 | | 10 | 18 | 1.80 |
| 16 | | | 17 | 12.5 | .74 |
| 17 | | | 44.5 | 16 | .36 |
| 18 | | | 17 | 34 | 2.00 |
| 19 | 3 | 5 | 48 | 19.5 | .41 |
| 20 | | | 1 | 9.5 | 9.50 |
| 21 | | | 1 | 7.5 | 7.50 |
| 22 | | | 47 | 26 | .55 |
| 23 | 3 | | 18 | 34.5 | 1.92 |
| 24 | 2.5 | | 28 | 24 | .86 |
| 25 | | | 33 | 26.5 | .80 |
| 26 | | | 27.5 | 28.5 | 1.04 |
| 27 | | | 25 | 24 | .96 |
| 28 | | | 1 | 14.5 | 14.5 |
| 29 | | | 44 | 36 | .82 |
| 30 | | | 12.5 | 15 | 1.20 |
| 31 | | 2 | 49 | 34.5 | .70 |
| 32 | | | 5 | 20 | 4.00 |
| 33 | | | 21 | 29 | 1.38 |
| 34 | | | 50 | 25 | .50 |
| 35 | 2.5 | | 29 | 23.5 | .81 |
| 36 | | | 40 | 23 | .56 |
| 37 | 2 | | 39 | 24 | .62 |
| 38 | | | 83 | 45 | .54 |
| 39 | | | 24 | 24 | 1.00 |
| 40 | | | 35 | 26 | .74 |
| 41 | 10 | | 68 | 48 | .71 |
| 42 | 2 | | 34 | 29 | .85 |

*No entry in either column indicates that no mechanical or electrical engineers charged time to the preparation of specifications.

80% complete. Rush projects frequently require starting specifications at 50% complete with the result that, since the architectural plans are not firm - and will undoubtedly change - much of the specifications will have to be rewritten. Unfortunately, there is no data available on when specifications were started with respect to the architectural plans.

Table IV also indicates that some projects require a minimum of typing time, assuming, of course, that hours charged to a job actually indicate hours worked. The typists report that quite frequently the specifications for an addition will be presented for typing as a marked up and corrected copy of the specifications for the original building. The typist will attempt to find and correct the masters for the original facility rather than retype the entire set of specifications. However, comparing typing hours for original buildings and subsequent additions reveals no consistent pattern. Apparently, the available storage space and the time interval between additions determines whether or not a set of specifications for an addition may be salvaged from the original masters.

In any event, it would be impossible to predict success in finding these masters and, thus, impossible to predict typing time. Likewise, it is impossible to predict the hours required to prepare a draft copy of specifications with no control over when the specifications will be started with respect to the per cent complete of the architectural plans. Therefore, the hours required to prepare specifications, at least the architectural and typing portions, were deleted from the study. However, the hours charged by mechanical and electrical engineers to the specifications category were shifted back to the mechanical and electrical sections. Thus, the mechanical and electrical portions of the analysis presented in the following chapter include the hours to prepare the plans and a rough draft of the specifications.

CHAPTER VI

THE FINAL INVESTIGATION

A detailed description of each project was obtained along with a complete accounting record of man-hours and costs. While the basic data was being collected, some projects were eliminated from further consideration for reasons such as:

(1) Multiple projects: Two or more schools under the same job number. All the man-hour and labor costs were lumped together so it would be impossible to determine the true design cost attributable to each project.

(2) Re-design: Projects that required complete redesign before going out for bids. Projects that were re-designed during the construction phase were also eliminated.

(3) Miscellaneous: Many projects were eliminated because they did not contain a satisfactory mix of classrooms. For instance, many additions might consist of just a cafetorium, a kitchen, or administrative space.

On the other hand, other projects that had been completed since the start of the investigation or simply overlooked, were included in the analysis.

The preliminary investigations indicated that both total man-hours and total dollar cost of those man-hours bore the same general graphical relationship to project size. Subsequent investigation would be

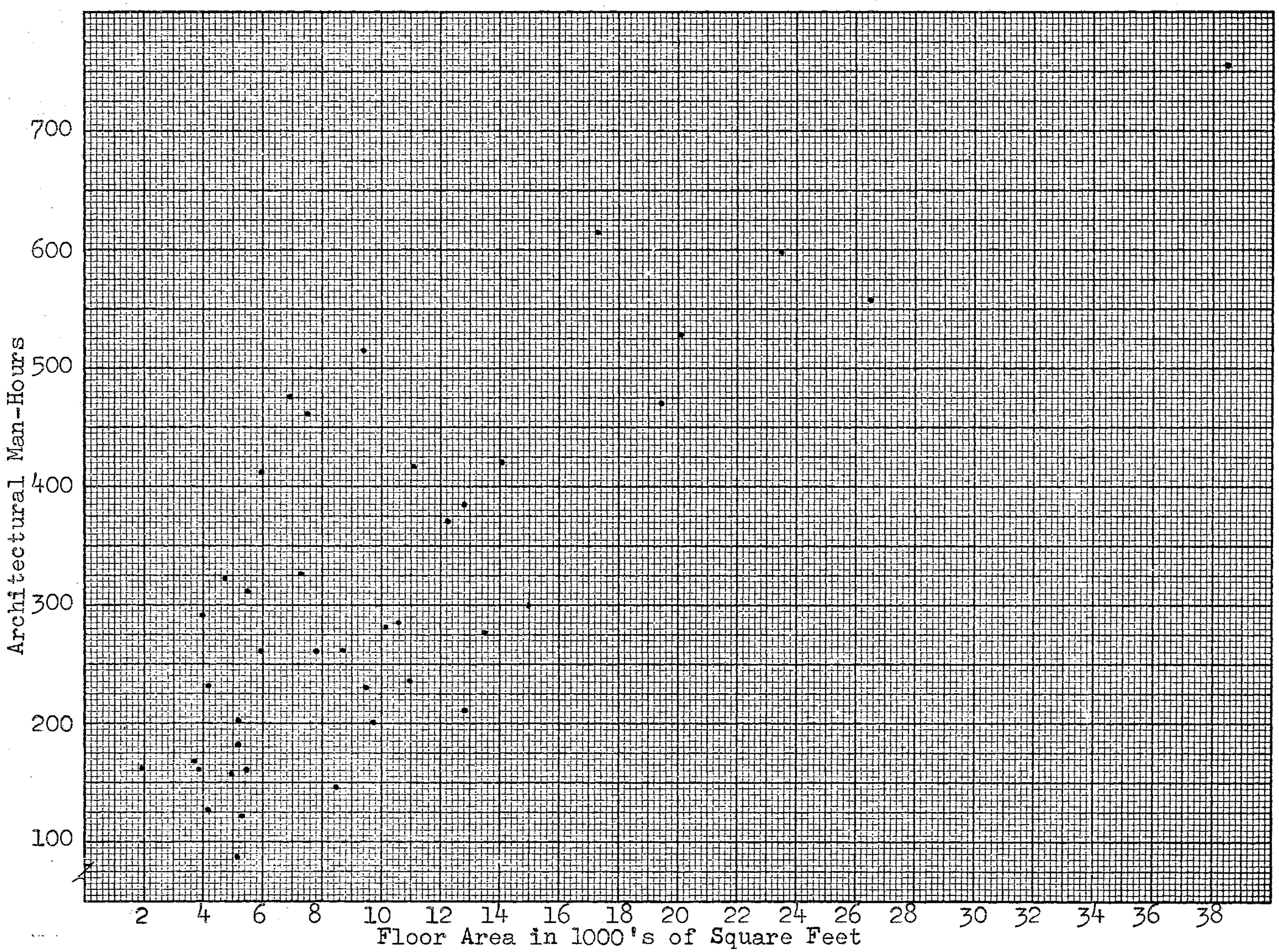



Figure 4. Architectural Man-Hour Requirements Versus Size of School

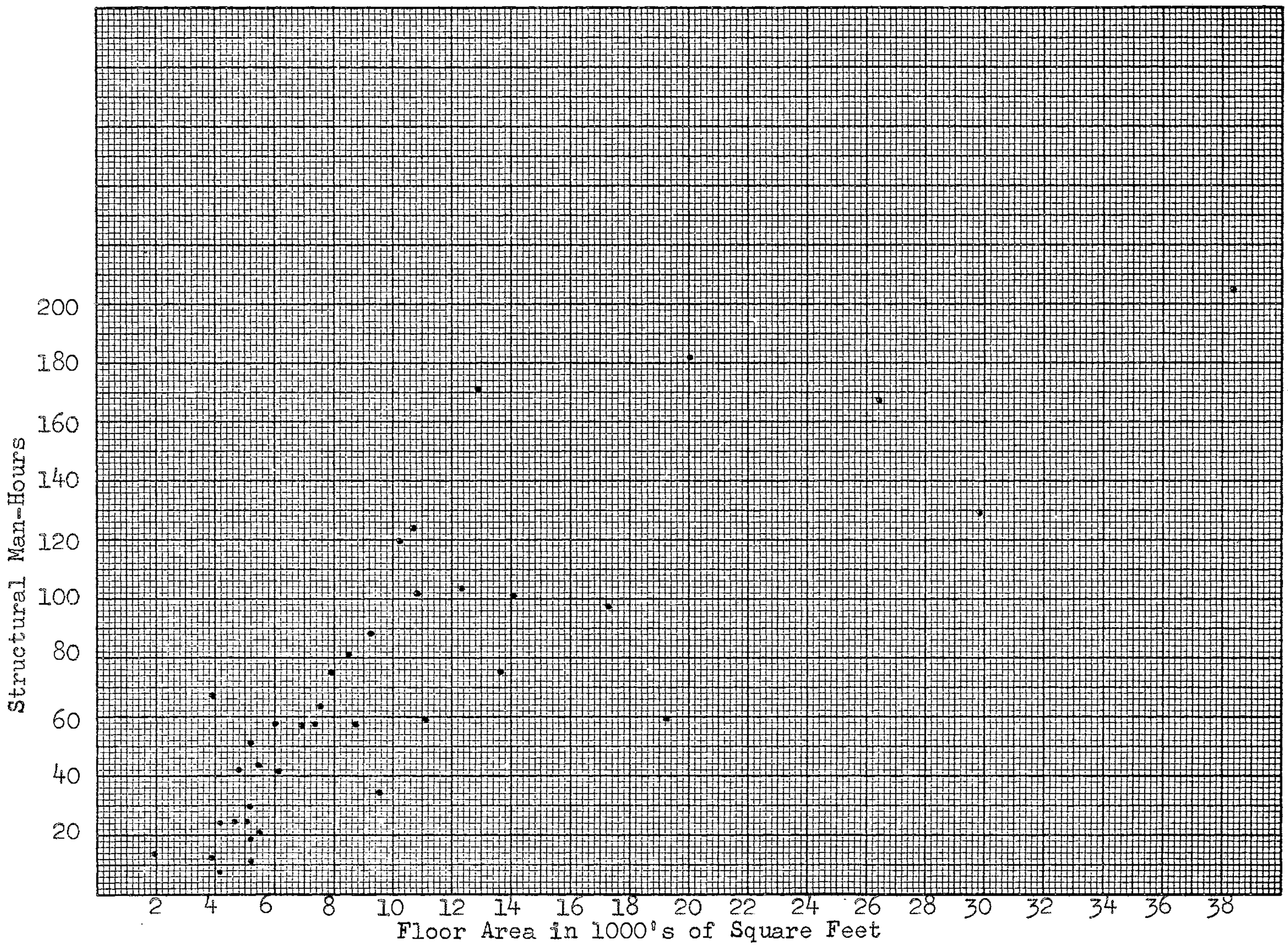



Figure 5. Structural Man-Hour Requirements Versus Size of School

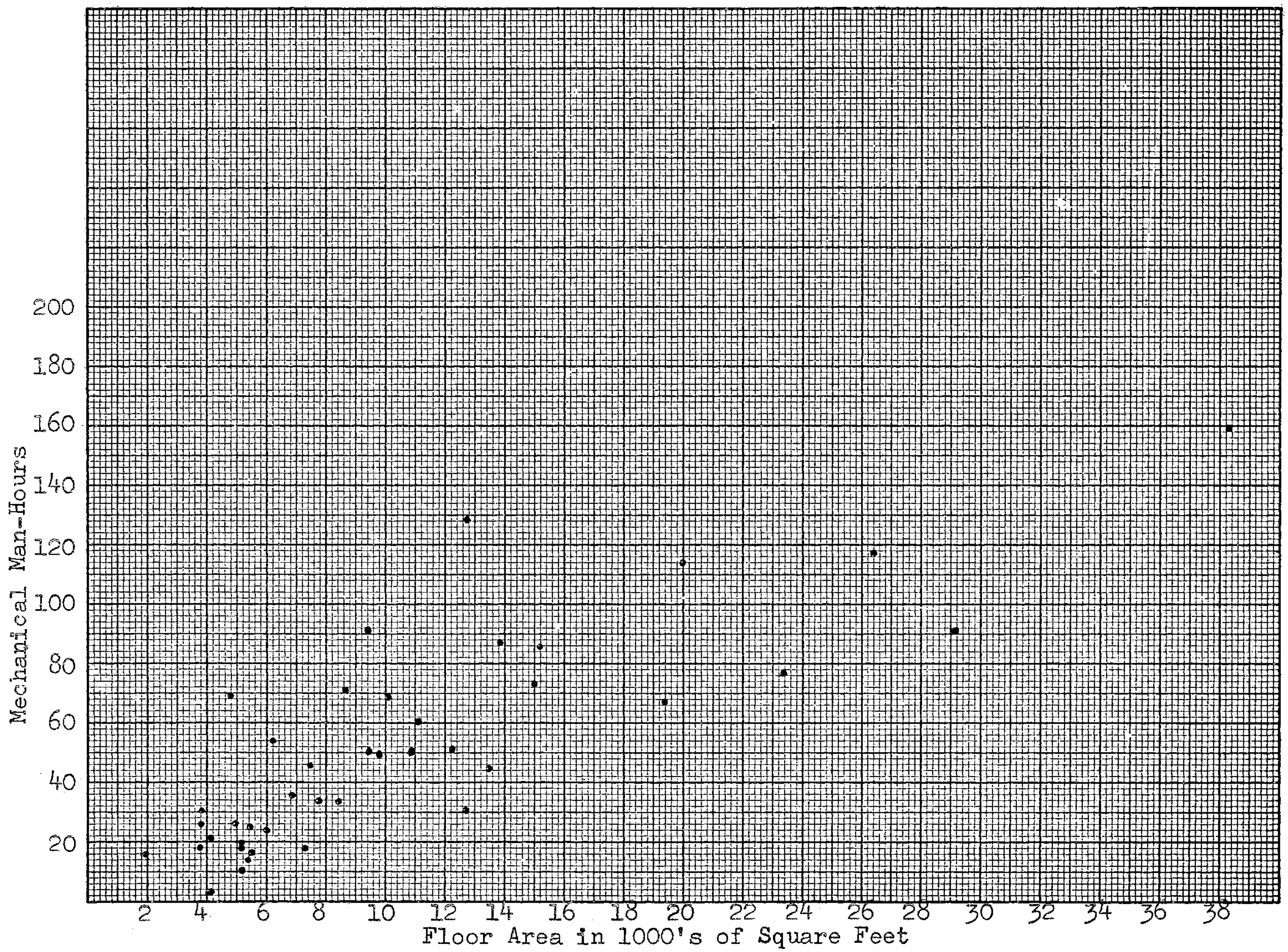



Figure 6. Mechanical Man-Hour Requirements Versus Size of School

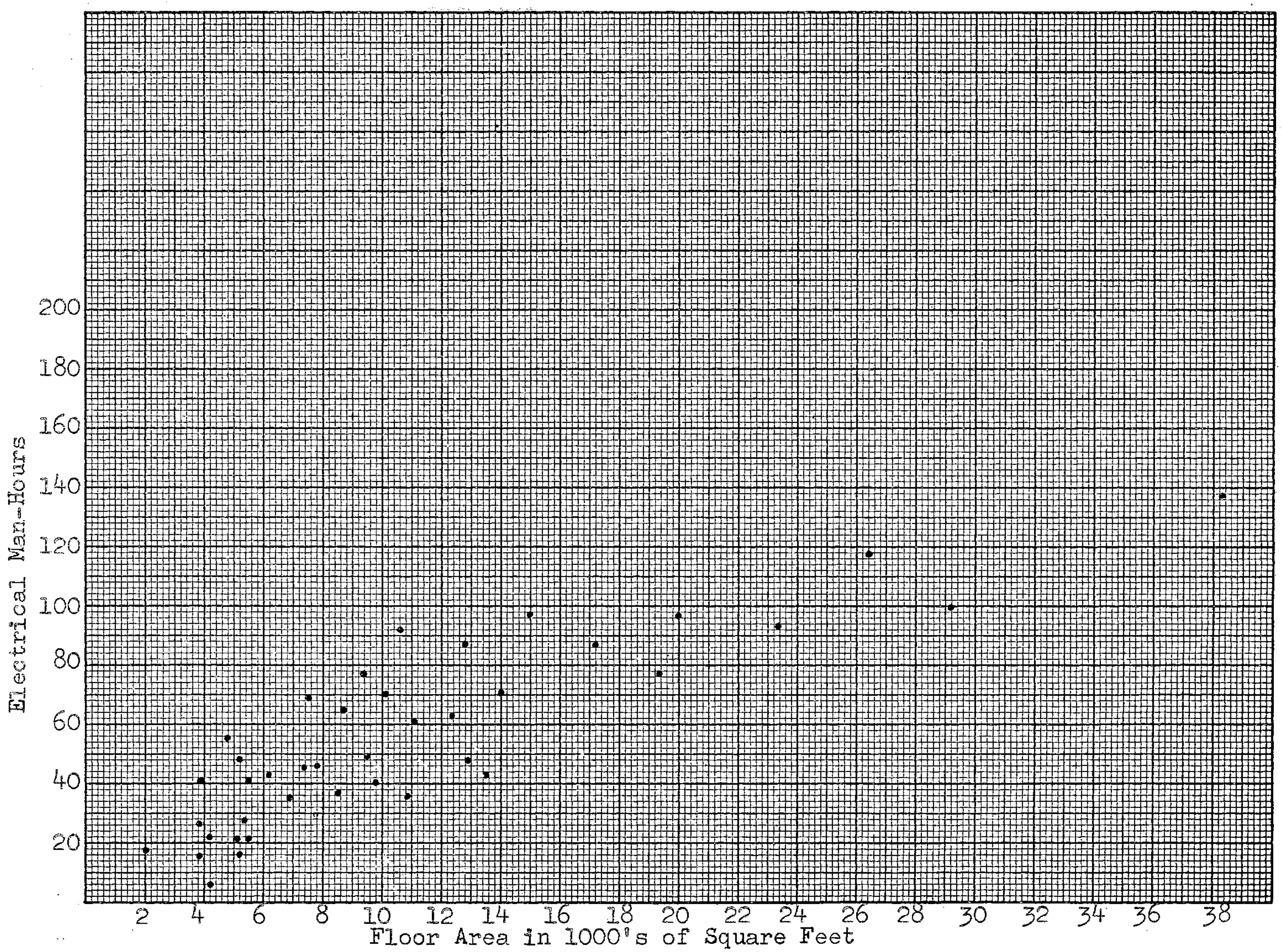



Figure 7. Electrical Man-Hour Requirements Versus Size of School

concerned with comparing ever increasing detailed information relative to project complexity with design costs. "Cost" in this instance referring to either man-hours or the dollar cost of those man-hours. A decision was required as to whether dollars or man-hours would be the base for pre-determining the effort, either in dollars or man-hours, required to prepare plans and specifications. The man-hour approach was selected for a variety of reasons. The logical extension of predetermining the man-hours required for a single project would be repetitive man-hour forecasts for multiple projects and establishing a controlled rate of production on the preparation of plans and specifications. Such scheduling could be accomplished on a dollar criteria but the implementation and maintenance of such a production schedule would be somewhat more difficult. In addition, the differences in productivity on man-hour basis would be accentuated with a dollar criteria. Finally, the contract is signed prior to any detailed information about the complexity of the project, and once the contract is signed, the architect is bound to provide plans and specifications regardless of costs.

Forty-one projects were now included in the analysis and the next phase was directed towards determining what relationship, if any, existed between the floor area of the school and the man-hours required to draw the plans. The basic data: the architectural, structural, mechanical, and the electrical man-hours required are presented as scatter diagrams in Figures 4 through 7. The following analysis and its description is similar in format for the architectural, structural, mechanical, and electrical specialties. In order to reduce the number of charts and figures presented in this section, only typical illustrations will be included. In general, only the architectural data will be presented and the charts and figures describing the same data for the structural, mechanical, and electrical specialties are included in the Appendix. Considerable effort was expended attempting to determine the family or type of mathematical expressions that best describe the scatter diagrams. The same data in Figures 4 through 7 was plotted on log-log- and semi-log co-ordinates, with assorted transformations of axes. The results were inconclusive. The inherent degree of scatter apparently precluded the possibility of deducing the family of mathematical relationships that would best express the data. The family $Y = a(x)^b$ looked somewhat promising and the curve expressing man-hours in terms of project size with this relationship for electrical man-hours is presented in Figure 8. The straightline expression through the same data is also presented in the same figure. The difference between the two expressions is insignificant considering the basic scattering in the data and their closeness through the middle portion of the graph. Because of the negligible difference between the two curves and the relative complexity of calculating with the exponential expression, the straightline equivalence will be used to determine the line of best fit for the scatter diagrams.

The straightline of best fit was calculated by the method of least squares for the architectural, structural, mechanical, and electrical portions of the man-hours required to prepare the plans. The graph for the architectural man-hours is presented in Figure 9. Similar graphs of the structural, mechanical, and electrical man-hour requirements are included in the Appendix. At the same time, a more detailed description of the projects was prepared. The description was broken down into six

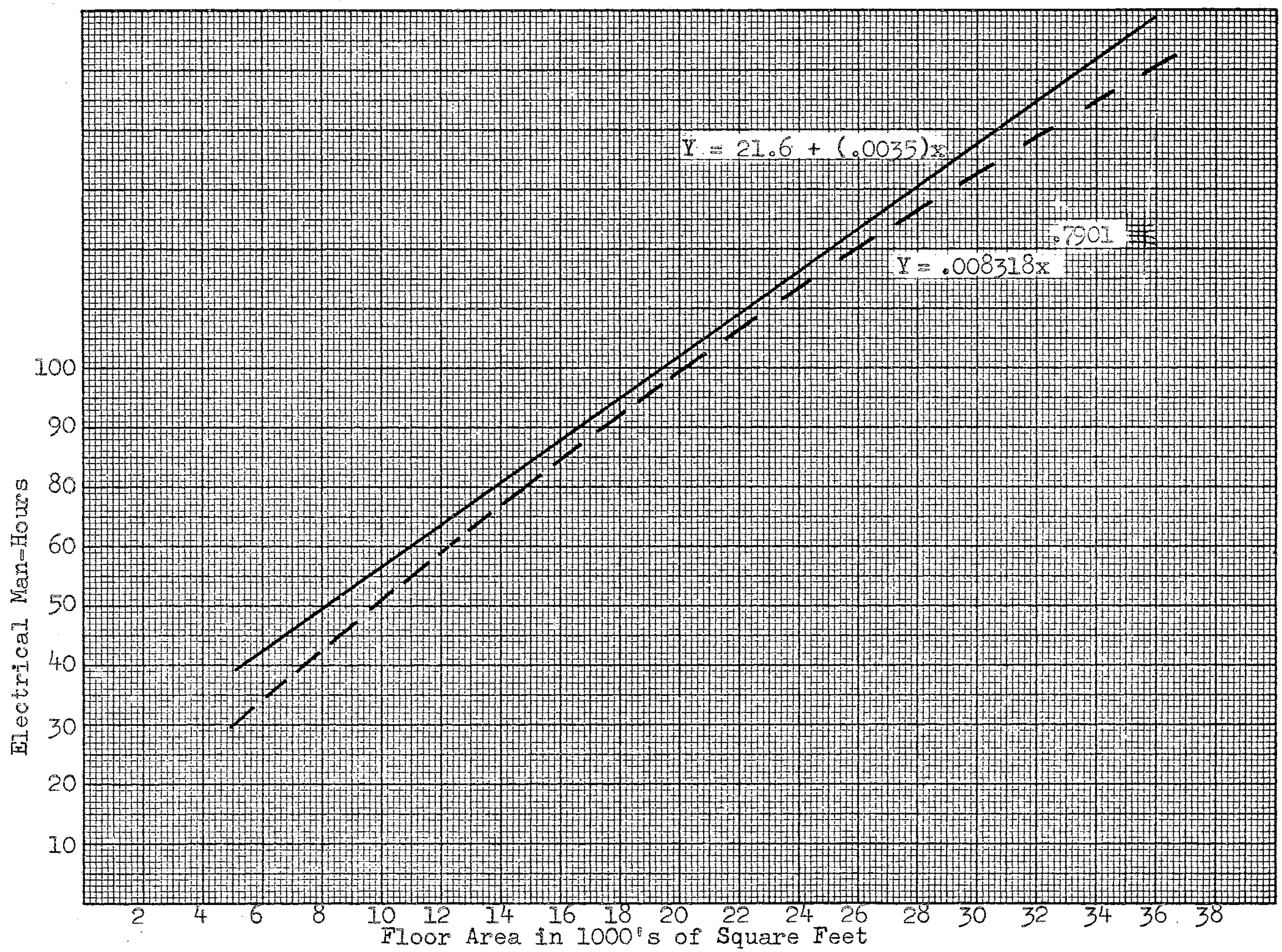



Figure 8. Comparison of Exponential and Straight Lines of Best Fit for Electrical Man-Hours

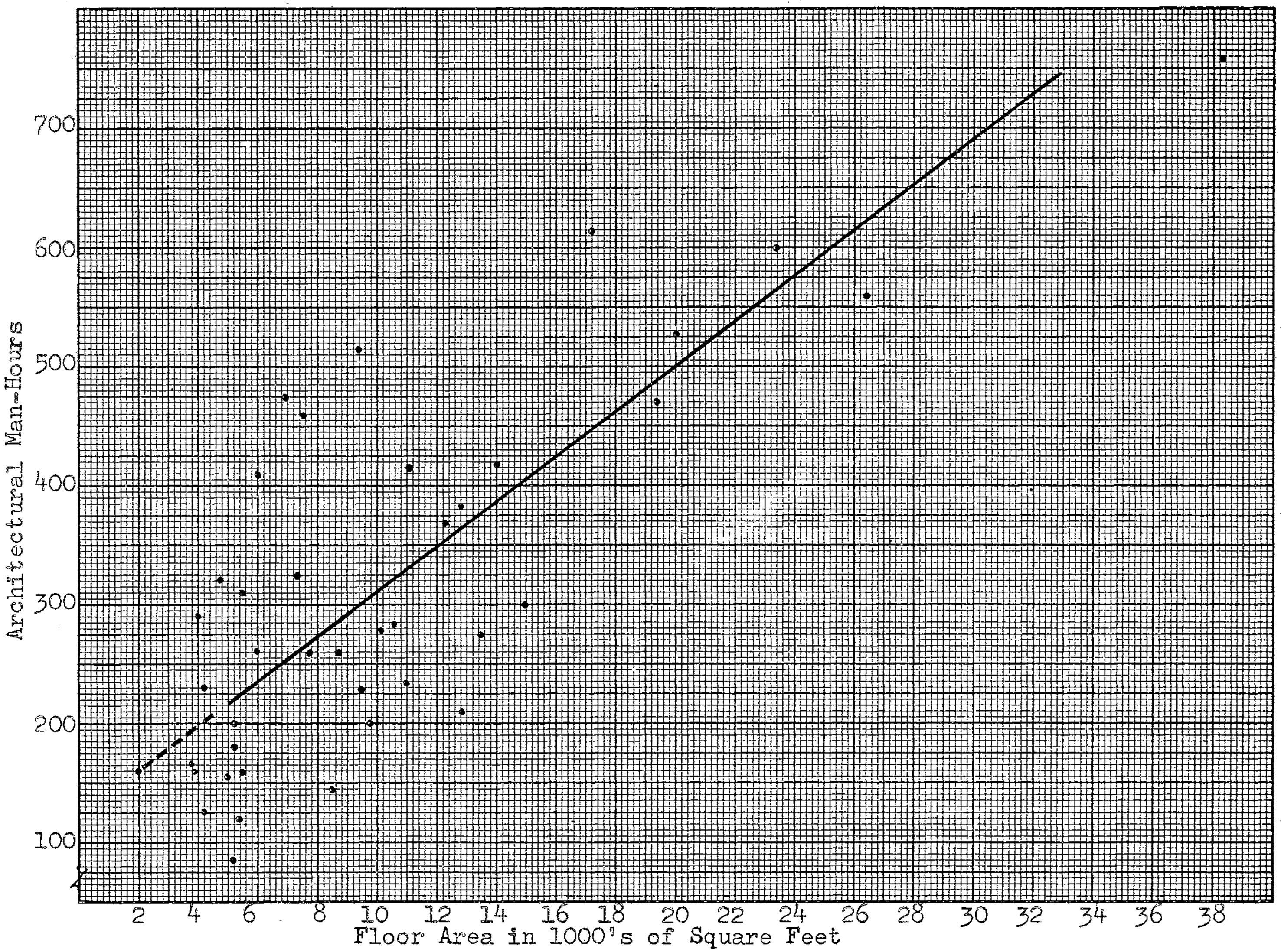



Figure 9. Straight-line of Best Fit for Architectural Man-Hour Requirements

groups in accordance with the range of areas encountered in the projects. The grouping is actually a legacy from an unsuccessful attempt to straight-line the data in short segments but has been maintained to reduce, somewhat, the amount of data that must be handled at the same time. A sample set of project descriptions is used in this phase of the study is presented in Figure 10. The same data was collected for all projects included in the analysis.

The deviation of each specialty from the average or expected value obtained by the method of least squares was calculated for each project. The deviations were either plus or minus, depending on whether or not the particular project lay above or below the line of best fit. The object was to obtain a series of factors from the project descriptions which, when multiplied by the expected value determined by least squares, would produce the actual value established from accounting records. This procedure is outlined in Figure 11.

The target factors were also calculated on the basis of

$$\text{Actual Value} = (\text{Expected Value})(d_1/d_2).$$

The factors determined by the above procedure would either be greater or less than unity depending upon whether the actual value was greater or less than the expected value. The factors could only be confirmed by this procedure, their actual construction was dependent on the items influencing complexity contained in the project descriptions. The difficulty with this approach was that the multiple items determining the difficulty of the project had to be combined in some manner to produce a single factor that when multiplied by the anticipated man-hours would adjust those hours in the amount and direction

GENERAL NOTES:

(1) The projects were assembled into six groups according to the floor area of each school. These groups were:

| | | |
|---|---|---|
| Group 2: | 5,000 - 6,000 S.F. | (7) |
| Group 3: | 6,000 - 8,000 S.F. | (6) |
| Group 4: | 8,000 - 11,000 S.F. | (7) |
| Group 5: | 11,000 - 15,000 S.F. | (6) |
| Group 6: | 15,000 S.F. and greater | (8) |

The figures in ( ) indicate the number of projects in each group.

(2) The grouping approached proved too cumbersome and was abandoned in favor of the tabular descriptions used in the final analysis. The groups were used, however, to calculate the lines of best fit.

(3) The data for Group 2 is presented in this example and the elaborating notes are summarized at the end of each specialized section. A summary of abbreviations concludes the figure.

| Project Number: | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|
| GENERAL DATA: | | | | | | | |
| Class (a) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Type (b) | El. | El. | El. | El. | El. | El. | Jr.-Sr. |
| Location (c) | MWC | MWC | PC | MWC | MWC | MWC | CHO |
| Size (in 1000's of S.F.) | 5.0 | 5.2 | 5.2 | 5.2 | 5.4 | 5.5 | 5.5 |
| New | | | | | | | |
| Addition | x | x | x | x | x | x | x |
| Complexity (d) | s | s | s | s | c- | c- | s |

NOTES:

(a) "1" and "2" both indicate single story construction, but "2" has special non-classroom areas such as cafeterias, etc. "3" indicates multi-story construction.

(b) El. for elementary or grade school; Jr. and Sr. for Jr. and Sr. High Schools. Non-specialized; blank

(c) MWC: Midwest City; PC: Putnam City; CHO: Choctaw

(d) s for simple and c for complex with + or -

Figure 10. Sample Set of Project Descriptions Used in the Intermediate Portion of the Analysis

| Project Number: | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|
| ARCHITECTURAL DATA: | | | | | | | |
| Teaching Stations | | | | | | | |
| Plain | 5 | 5 | 5 | 4 | 5 | 4 | 5 |
| Primary | | | | | | | |
| Special | | | | | | | |
| Sci.-Bio.-Phys. | | | | | | | |
| Art-Bus. | | | | | | | |
| Music-Math | | | | | | | |
| Total | 5 | 5 | 5 | 4 | 5 | 4 | 5 |
| Other Areas | | | | | | | |
| Lobbies | | | | | | | |
| Corridors | 2 | 1 | 1 | 2 | 2 | 2 | 2 |
| Closets (storage) | | | | | | | |
| Closets (custodial) | | | | 1 | 1 | 1 | 1e |
| Dining Room | | | | | | | |
| Work Room | | | | | | | |
| Storage Rooms | | | | 1 | | 1 | |
| Lounge | | | | | | | 1f |
| Dark Rooms | | | | | | | |
| Library | | | | | | | |
| Offices | | | | | | | |
| Counseling | | | | | | | |
| Toilets | | | 2 | 2 | 2 | 2 | 2 |
| Gym | | | | | | | |
| Kitchen | | | | | | | |
| All Purpose Room (APR) | | | | | | | |
| Cafe | | | | | | | |
| Total Rooms | 7 | 6 | 8 | 10 | 10 | 10 | 11 |
| Miscellaneous | | | | | | | |
| Total Fixtures in Toilets | | | 13 | 14 | 14 | 13 | 9 |
| Stage | | | | | | | |
| Remodel/Demolition | | g | | | | | |
| Remarks | hi | hi | jk | ki | hi | hi | |

(e) no sink
(f) with toilet
(g) remove septic tank
(h) teacher and heater closet in each classroom and borrow lights between classroom and corridor
(i) lavatory in each classroom
(j) slight amount of re-design
(k) teacher and heater closet in each classroom

Figure 10. (Continued)

| Project Number: | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|
| STRUCTURAL DATA | | | | | | | |
| FOUNDATION: | | | | | | | |
| drill piers | x | x | | x | | | x |
| spot footings | | | x | | | | |
| spread footings | | | | | xm | x | |
| EXTERIOR WALLS: | | | | | | | |
| 1' - 1" masonry cavity | x | x | x | x | x | x | x |
| structural tile | x | | | | | | |
| load bearing | x | x | x | x | x | x | x |
| non-load bearing | | | | | | | |
| window wall | | | | | | | |
| INTERIOR WALLS: | | | | | | | |
| block | | | x | x | x | x | x |
| tile | xl | xl | | | | | |
| load bearing | x | x | x | x | x | x | x |
| non-load bearing | | | | | | | |
| ROOF: | | | | | | | |
| bar joist | | | | | | | x |
| metal deck | | | | | | | x |
| concrete | | | | | | | |
| built-up roof | | | | | | | |
| wood joists | x | x | | x | x | x | |
| wood deck | x | x | | x | x | x | |
| laminated wood beams | | | x | | | | |
| tectum deck and bulb tees | | | x | | | | |
| rigid insulation | | | | | | | |
| MISC.: | | | | | | | |
| tube columns | | | | | | | |
| conc. columns and p. joists | | | | | | | |
| removable pan joists | | | | | | | |

(l) plastered
(m) continuous

Figure 10. (Continued)

| Project Number: | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|
| MECHANICAL DATA: | | | | | | | |
| Heating System | | | | | | | |
| individual room units | | | | | | | |
| closet forced air | x | x | x | x | x | | |
| wall convection | | | | | | x | |
| space heaters | | | | | | | |
| central systems | | | | | | | |
| forced air | | | | | | | |
| hot water | | | | | | | |
| Air Conditioning | | | | | | | |
| Toilets (number of rooms) | | | | 2 | 2 | 2 | 2 |
| total fixtures | | | | 14 | 14 | 13 | 9 |
| Special Classrooms | | | | | | | |
| science | | | | | | | |
| primary | | | | | | | |
| other | | | | | | | |
| Gym | | | | | | | |
| Kitchen | | | | | | | |
| Mechanical Areas | 4 | 5 | | 6 | 8 | 1 | 4 |
| total fixtures | 4 | 5 | | 19 | 20 | 14 | 11 |
| Remarks | p | o | | o | o | o | n |

(n) toilet in teachers' lounge plus sink in one classroom
(o) lavatory in each classrooms
(p) lavatory in four of five classrooms

Figure 10. (Continued)

| Project Number: | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|
| ELECTRICAL DATA: | | | | | | | |
| Lighting: | | | | | | | |
| fluorescent | x | x | q | x | x | | |
| incandescent | | | r | | | | |
| Sound/Intercom System | | | | | s | | |
| Clock/Bell Program | | | | | x | | |
| Kitchen | | | | | | | |
| Office | | | | | | | |
| Gym | | | | | | | |
| All Purpose Room (APR) | | | | | | | |
| Cafeteria | | | | | | | |
| Auditorium | | | | | | | |
| Stage | | | | | | | |

(q) suspended in classrooms
(r) recessed in corridor
(s) rough in only

Figure 10. (Continued)

necessary to approximate the actual man-hours required. Too much information had to be handled simultaneously and the analysis broke down under the burden. A different approach was required.

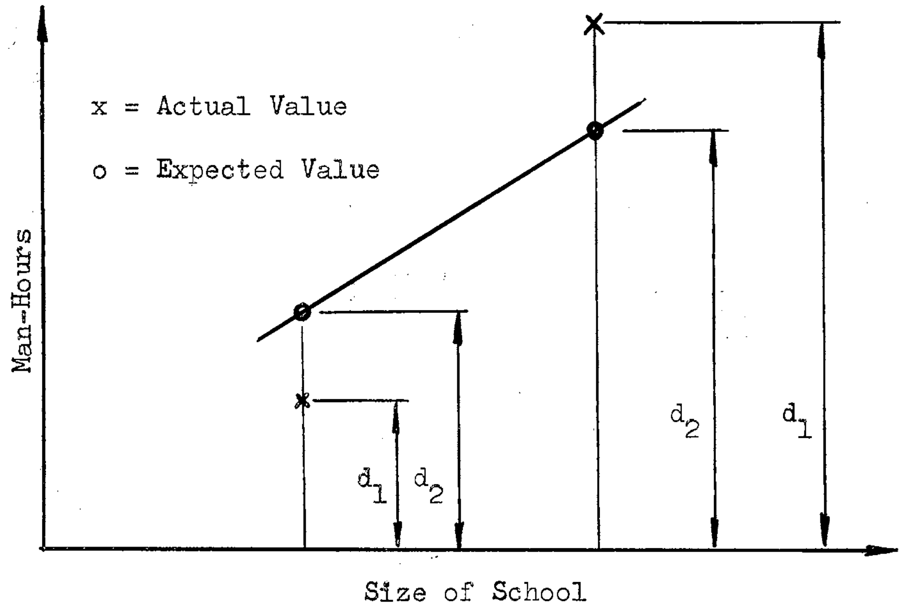



Figure 11. Example of Determining the Deviation Between Actual and Average Man-hour Requirements

The principal problem was the adding together of contributing factors to produce a single multiplying factor that could be greater or less than unity. This problem could be circumvented by lowering the line of best fit so that it lay graphically below the data so that all adjusting factors would be greater than unity. The slope would be maintained, but the intercept shifted. This procedure is presented in Figure 12.

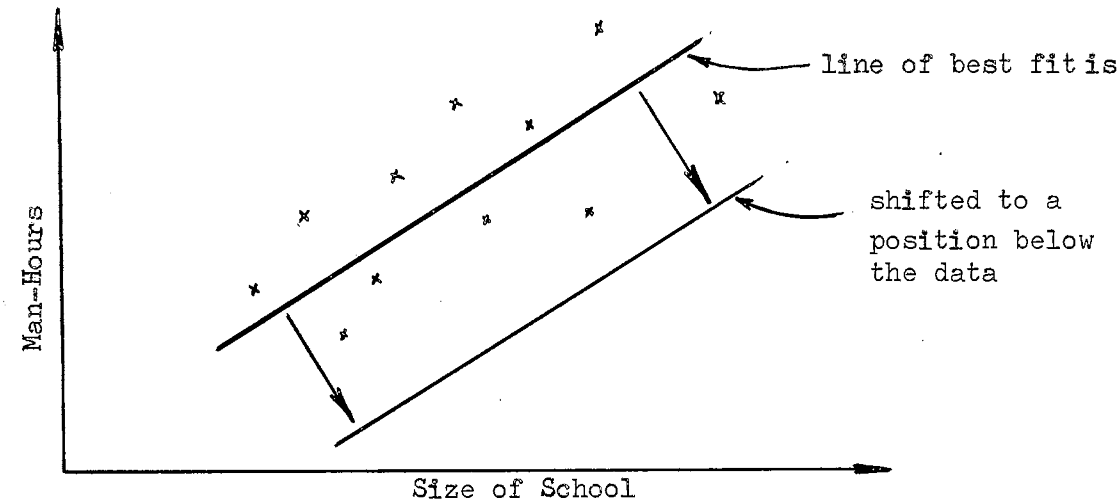



Figure 12. Example of Lowering the Line of Best Fit so That all the Data Deviates From the Base Line in One Direction

With this approach, the multiple factors affecting project difficulty could be considered man-hour allowances. The lowered line of best fit will be used as a base to determine the minimum man-hour requirements for projects in accordance with their size. The minimum figure will be increased with appropriate man-hour allowances necessary to reflect the difficulty or complexity of the project.

Figure 13 depicts the straight line of best fit for the electrical, mechanical, structural, and architectural man-hours required to prepare the plans for each project. The total man-hours for the four specialties is also shown in the same figure. Note that the graphical presentations for the electrical and mechanical man-hour requirements are almost coincident. The structural man-hour requirements exceed both the electrical and mechanical and, in addition, the slope is somewhat steeper. Architectural requirements, on the other hand, are

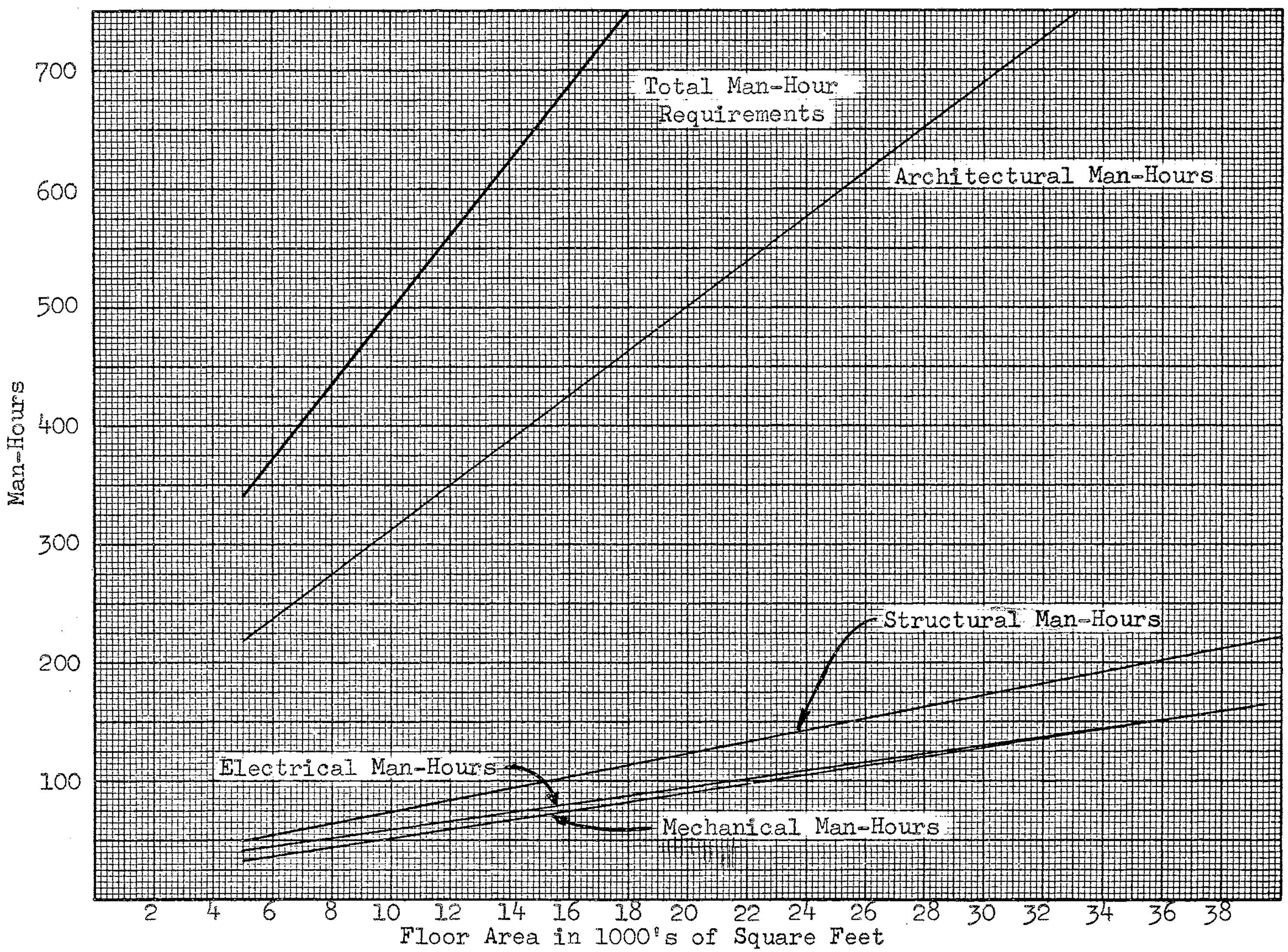



Figure 13. Straight-lines of Best Fit for Architectural, Structural, and Electrical Man-Hour Requirements

considerably steeper than either of the other three specialties (electrical, mechanical, and structural) composing total man-hour requirements.

The graphs showing the lowered lines of best fit for the architectural man-hours is presented in Figure 14. The vertical distance between the lowered lines of best fit for each specialty was calculated and are summarized in the Appendix. The deviations between the lowered line of best fit and the actual man-hour requirements are the target values for the man-hour allowances which will be based on the complexity of the project.

The previously presented project descriptions proved too cumbersome in their application, so a new method of presenting the same data was prepared. The new project descriptions were broken down by specialty rather than area. The new project descriptions for the architectural portion is presented in Table V. As it happened, even the new format was too cumbersome in application. The projects were, therefore, subdivided in order to reduce the volume of data that had to be considered simultaneously while attempting to determine a consistent set of man-hour allowances based on project complexity. The projects were divided into four groups in accordance to their location and whether they were a new school or an addition. The four divisions are:

1. Oklahoma City (and its environs)
    a. New schools
    b. Additions
2. Remote Locations
    a. New schools
    b. Additions.

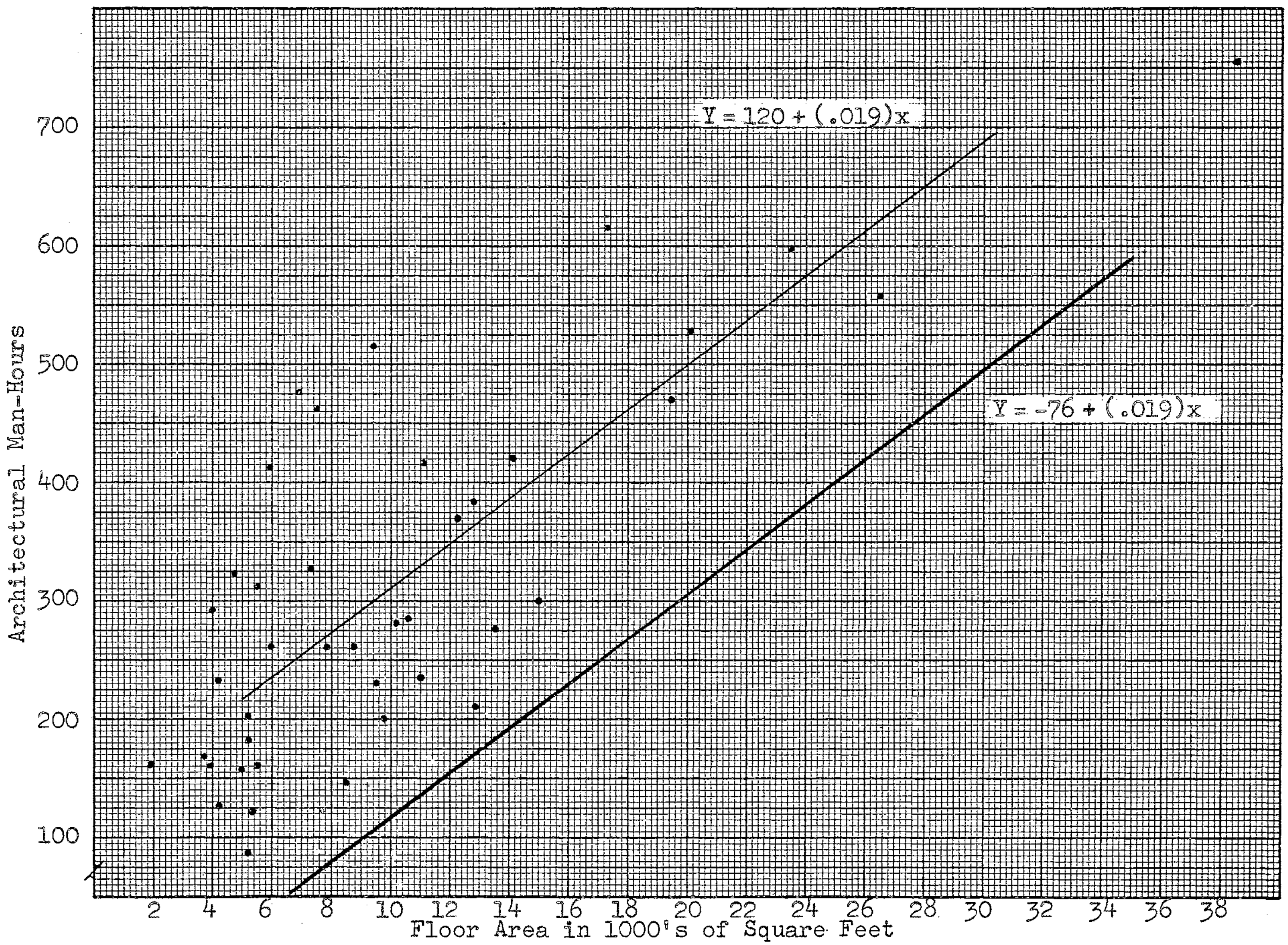



Figure 14. Lowered Line of Best Fit for Architectural Man-Hours

## TABLE V

### TABULAR DESCRIPTION OF ARCHITECTURAL ASPECTS OF PROJECTS INCLUDED IN ANALYSIS

| Project No. | Location | El. | Jr.Sr. | New | Add * | Date | Class | Tea. Sta. | Spec. Clas. | Cafe | Kitch | Apr | Gym | Stage | Off. | Rem. | Toilets | Misc. | Tot. Rms. | Area (1000's) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | MWC | x | | | S | 2.64 | 1 | 5 | - | - | - | - | - | - | - | | - | (A)(B) | 7 | 5.0 |
| 9 | MWC | x | | | S | 3.63 | 1 | 5 | - | - | - | - | - | - | - | | - | (A)(B) | 6 | 5.2 |
| 10 | P.C. | x | | | S | 11.62 | 1 | 5 | - | - | - | - | - | - | - | | - | (C) | 8 | 5.2 |
| 11 | MWC | x | | | S | 2.64 | 1 | 4 | - | - | - | - | - | - | - | | 2 | (B) | 10 | 5.2 |
| 12 | MWC | x | | | C- | 2.64 | 1 | 5 | - | - | - | - | - | - | | | 2 | (A)(B) | 10 | 5.4 |
| 13 | MWC | x | | | C- | 3.63 | 1 | 4 | - | - | - | - | - | - | | | 2 | (A)(B) | 10 | 5.5 |
| 14 | Choctaw | | x | | S | 4.64 | 1 | 5 | - | - | - | - | - | - | | | 2 | | 11 | 5.5 |
| 15 | MWC | | x | | S | 3.62 | 3 | 4 | 2 | | | | | | | | 2 | | 10 | 6.0 |
| 16 | P.C. | x | | | C | 1.64 | 1 | 6 | 2 | | | | | | | | 2 | | 9 | 6.1 |
| 17 | Dunjee | x | | | C | 4.64 | 2 | 6 | | | 4R** | | | | | x | | | 11 | 6.9 |
| 18 | Crutcho | | | | S | 6.64 | 1 | 6 | 1 | | | | | | | | | (B)(D) | 9 | 7.3 |
| 19 | Cherokee | | x | | S | 4.61 | 1 | 5 | 1 | | | | | | | | 2 | | 10 | 7.5 |
| 20 | MWC | | x | | S | 3.65 | 3 | 6 | | | | | | | | | 4 | (E)(F) | 14 | 7.8 |
| 21 | MWC | | x | | S | 3.65 | 3 | 6 | - | | | | | | | | 4 | (G) | 13 | 8.5 |
| 22 | Ralston | | | | C | 5.61 | 2 | 4 | 1 | 1 | 6R | | | S | | x | | | 16 | 8.7 |
| 23 | Burns Flat | x | | N | | 5.62 | 2 | 5 | - | 1 | 4 | | | | 1 | x | 2 | | 14 | 9.4 |
| 24 | MWC | x | | N | | 3.63 | 1 | 6 | 2 | | | | | | 4 | | 2 | (A)(B) | 18 | 9.5 |
| 25 | Edmond | x | | | S | 2.65 | 1 | 6 | - | | | | | | | | 4 | (B) | 15 | 9.8 |
| 26 | P.C. | x | | | C | 1.64 | 3 | 8 | 2 | | | | | | | | 2 | (E) | 17 | 10.1 |
| 27 | P.C. | | x | | S | 2.63 | 3 | 8 | 1 | | | | | | | | 4 | | 18 | 10.6 |
| 28 | MWC | | x | | S | 3.65 | 3 | 8 | 1 | | | | | | 1 | | 4 | | 19 | 11.0 |
| 29 | Edmond | x | | | C | 4.63 | 2 | 4 | - | 1 | 5R | | | S | 1 | | 4 | (C)(B) | 23 | 11.1 |
| 30 | MWC | | x | | S | 3.63 | 3 | 8 | 3 | | | | | | - | (I) | | (E) | 15 | 12.3 |
| 31 | Depew | x | | N | | 5.61 | 2 | 8 | 2 | 1 | 4 | | | | 1 | | 2 | | 23 | 12.8 |
| 32 | Hartshorn | | x | | S | 8.64 | 1 | 10 | 3 | | | | | | 3 | | 2 | | 20 | 12.9 |
| 33 | P.C. | x | | | S | 11.64 | 3 | 12 | 1 | | | | | | - | | 2 | | 23 | 13.5 |
| 34 | Butler | | x | N | | 4.62 | 2 | 7 | 2 | | 5 | | | S | 3 | (J) | 4 | | 27 | 14.0 |
| 35 | MWC | | x | | S | 3.63 | 3 | 10 | 5 | | | | | | - | | 4 | | 18 | 15.0 |
| 36 | Heavener | | x | N | | 11.61 | 1 | 11 | 5 | | | | | | 5 | | 4 | | 31 | 17.2 |
| 37 | Edmond | x | | N | | 2 62 | 2 | 12 | 2 | 1 | 6 | | | S | 4 | | 2 | | 30 | 19.4 |
| 38 | Cushing | x | | | S | 6.61 | 2 | 10 | 5 | 1 | 9 | | | | 1 | | 2 | | 30 | 20.0 |
| 39 | MWC | | x | N | | 3.62 | 3 | 11 | 3 | | | 1 | | | | | 4 | | 31 | 23.4 |
| 40 | Millwood | | | | S | 12.61 | 2 | 10 | 1 | | | | 9 | | | | 2 | | 29 | 26.4 |
| 41 | Nicoma Park | | x | N | | 3.63 | 2 | 10 | 3 | 1 | 5 | | 6 | | 2 | | 2 | | 36 | 29.2 |
| 42 | P.C. | | x | | S | 12.60 | 3 | 30 | - | 1 | 5 | | | S | 3 | | 4 | | 58 | 38.3 |

(A) Borrow Lts
(B) Lavs in Classrms
(C) Plan Re-Design
(D) Two separate Add'ns
(E) Two Story Add'n to one story school
(F) Add'n Spans Kitch.
(G) Window Wall
(H) Basement
(I) Remodel of Home Ec. area in another school
(J) Remodel another School (Slight)

*S and C indicate simple or complex additions
**R designates some re-model work

It should be noted that the grouping is not arbitrary. There may be a detectable difference in the man-hours required to prepare the plans for a school in the Oklahoma City area as compared to the requirements for a facility in an area remote from the Oklahoma City office that was responsible for preparing the plans. Along this same line, there may be a detectable difference between the man-hours required to prepare the plans for a new school and the man-hour requirements for an addition to existing facility. The premise for both of these possibilities is that the man-hour requirements should increase as the difficulty of effective communication increases. Also, the communication difficulties are somewhat less for an addition than a new school, particularly if "as built" plans for the building to be expanded are available.

By trial and error, a set of man-hour allowances were built up from the project descriptions, plans, specifications, and the project's individual deviation from the lowered line of best fit. The architects, engineers, and draftsmen responsible for the preparation of plans and specifications were questioned as to their feeling for what allowances should be made for the various factors that make each project somewhat distinct. The man-hours allowances were developed so as to be consistent with the tabular project descriptions. The architectural man-hour allowances in the same format as Table V are presented in Table IV. Similar man-hour allowances for the structural, mechanical, and electrical specialties are in the Appendix.

The object in determining these various allowances was to reduce, but if possible not exceed, each project's deviation from the lowered line of best fit. Figure 15 demonstrates the degree of success achieved

# TABLE VI

## ARCHITECTURAL MAN-HOUR ALLOWANCES

| Project No. | Diff. Between Allow. and Dev. Under | Over | Actual Dev. | Total Allow. | Location | Jr/Sr Hi | Add'n (Complex-ity) | Two Story | Special Classrms | Primary | Kitch | Gym | Stage | Off. | Toilets Mul-tiple | Single | Class-Room Lavs. | Bor-row Lights | Remodel | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 97 | | 107 | 10 | | | | | | | | | | | | | 2 | 8 | | |
| 9 | 126 | | 136 | 10 | | | | | | | | | | | | | 2 | 8 | | |
| 10 | 160 | | 168 | 8 | | | | | | | | | | | 8 | | | | | 20(A) |
| 11 | 43 | | 60 | 17 | | | | | | | | | | | 8 | | 1 | 8 | | |
| 12 | 55 | | 93 | 38 | | | 20 | | | | | | | | 8 | | 2 | 8 | | |
| 13 | 104 | | 133 | 29 | | | 20 | | | | | | | | 8 | | 1 | | | |
| 14 | 252 | | 281 | 29 | | 16 | | | | | | | | | 8 | 4 | 1 | | | |
| 15 | 321 | | 369 | 48 | | 16 | | 16 | 8 | | | | | | 8 | | | | | |
| 16 | 187 | | 219 | 32 | | | 20 | | | 4 | | | | | 8 | | | | | |
| 17 | 283 | | 419 | 136 | | | 40 | | | | 16 | | | | | | | | 80 | |
| 18 | 241 | | 260 | 19 | | | | | | 2 | | | | | | | 1 | | | 16(C) |
| 19 | 363 | | 391 | 28 | | 16 | | | 4 | | | | | | 8 | | | | | |
| 20 | 61 | | 181 | 88 | | 16 | | 16 | | | | | | | 16 | | | | | 40(E) (F) |
| 21 | 12 | | 60 | 48 | | 16 | | 16 | | | | | | | 16 | | | | | |
| 22 | 23 | | 167 | 144 | | | 40 | | 4 | | 16 | | 4 | | | | | | 80 | |
| 23 | 145 | | 413 | 268 | 160 | | | | | | 16 | | | 4 | 8 | | | | 80 | |
| 24 | 86 | | 128 | 42 | | | | | | 4 | | | | 16 | | 4 | 2 | 8 | | |
| 25 | 73 | | 90 | 17 | | | | | | | | | | | 16 | | 1 | | | |
| 26 | 101 | | 165 | 64 | | | | 16 | | 4 | | | | | | 4 | | | | |
| 27 | 4 | | 60 | 56 | | 16 | | 16 | 8 | | | | | | 16 | | | | | |
| 28 | 48 | | 104 | 56 | | 16 | | 16 | 4 | | | | | 4 | 16 | | | | | |
| 29 | 61 | | 279 | 129 | | | 40 | | | | 16 | | 4 | 4 | 16 | | 1 | 8 | | 40(B) |
| 30 | 91 | | 215 | 124 | | 16 | | 16 | 12 | | | | | | | | | | 40(G) | 40(E) |
| 31 | 15 | | 219 | 204 | 160 | | | | | 4 | 16 | | | 4 | 8 | 4 | | | | 8(D) |
| 32 | | 8 | 40 | 48 | | 16 | | | 12 | | | | | 12 | 8 | | | | | |
| 33 | 73 | | 93 | 20 | | | | 16 | 4 | | | | | | | | | | | |
| 34 | 7 | | 231 | 224 | 160 | 16 | | | | | 16 | | 4 | 12 | 16 | | | | | |
| 35 | 17 | | 86 | 69 | | 16 | | 16 | 20 | | | | | | 16 | | 1 | | | |
| 36 | 96 | | 364 | 228 | 160 | 16 | | | 16 | | | | | 20 | 16 | | | | | |
| 37 | | 29 | 179 | 208 | 160 | | | | | 4 | 16 | | 4 | 16 | 8 | | | | | |
| 38 | 222 | | 267 | 45 | | | | | 12 | 4 | 16 | | | 4 | 8 | | 1 | | | |
| 39 | 166 | | 230 | 64 | | 16 | | 16 | 12 | | | | | | 16 | 4 | | | | |
| 40 | 113 | | 133 | 20 | | | | | 4 | | | 8 | | | 8 | | | | | |
| 41 | 122 | | 350 | 228 | 160 | 16 | | | 12 | | 16 | 8 | | 8 | 8 | | | | | |
| 42 | 28 | | 108 | 80 | | 16 | | 16 | | | 16 | | 4 | 12 | 16 | | | | | |

(A) Some redesign
(B) Considerable redesign
(C) Two sep. addn's
(D) Basement
(E) Two story add'n to a one story school
(F) Add'n spans kitch.
(G) Remodel Home Ec. area in another school

by this approach for new schools in remote locations (Group 2-A). In each figure, the individual project deviation from the base line is represented as a bar graph. The shaded portion of the bars indicates the amount of each project's deviation that may reasonably be attributed to the complexity of the specific project. Note that in a few cases the allowances "over-adjusted" the base figure so that the forecast man-hour requirements exceed actual performance. Ideally, the allowances should shade in the entire column on the bar graph and the discrepancy between the synthetic man-hour requirements and the actual performance should be reduced to zero. A few "over-adjusted" projects were inevitable if a consistent set of man-hour allowances was to be obtained. These allowances are the product of innumerable round trips through the data and represent the best set of allowance for over-all performance.

Certain structural, mechanical, and electrical man-hour allowances are relatively straightforward. For instance, the mechanical man-hours will understandably be increased when the project requires central air-conditioning. The necessity for such allowances is also readily apparent from the project deviations. Other allowances are not quite so apparent. The architectural man-hour deviations virtually defy description.

New schools in remote locations (Class 2-A) is the most consistent classification of the projects included within the study. Note the allowance for the remote locations reduces the over-all difference between anticipated and actual performance to reasonable limits. The other three project classifications were not consistent enough to warrant similar allowances.

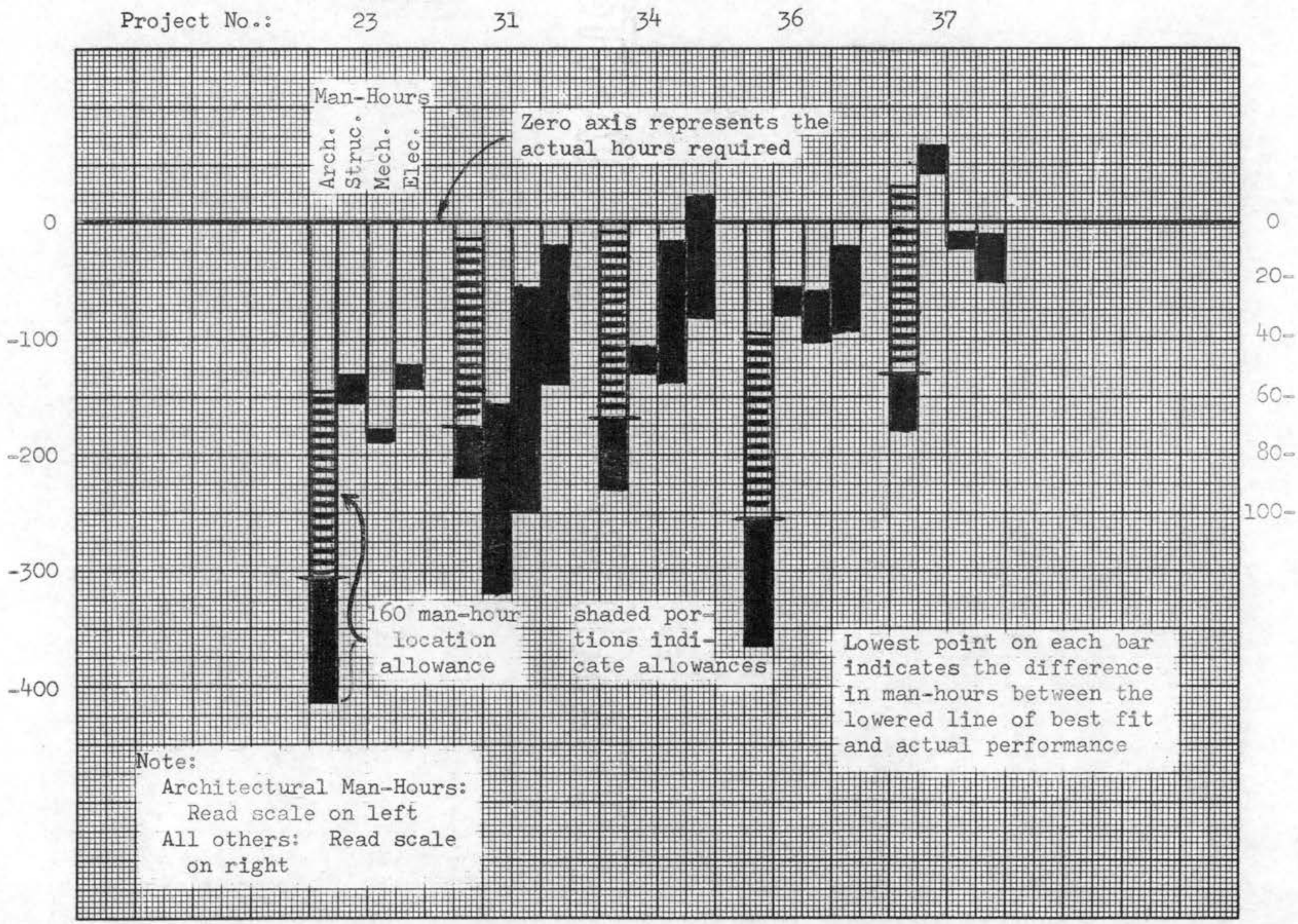



Figure 15. Effect of Man-Hour Allowances on Group 2.a

Figure 16 presents the same graphical relationships between the man-hour allowances and actual performance for all projects not included in Figure 15. Figure 16 is in precisely the same format as Figure 15 with the shaded portion of each bar representing the total man-hour allowances for each project. Figure 16, however, does not include any across the board man-hour allowances for either the type of school, new or addition, or the location of any specific project with respect to the Oklahoma City office. Table VII summarizes the various man-hour allowances for the assorted features relating to project difficulty. The project descriptions used to develop Table VII are contained in the Appendix.

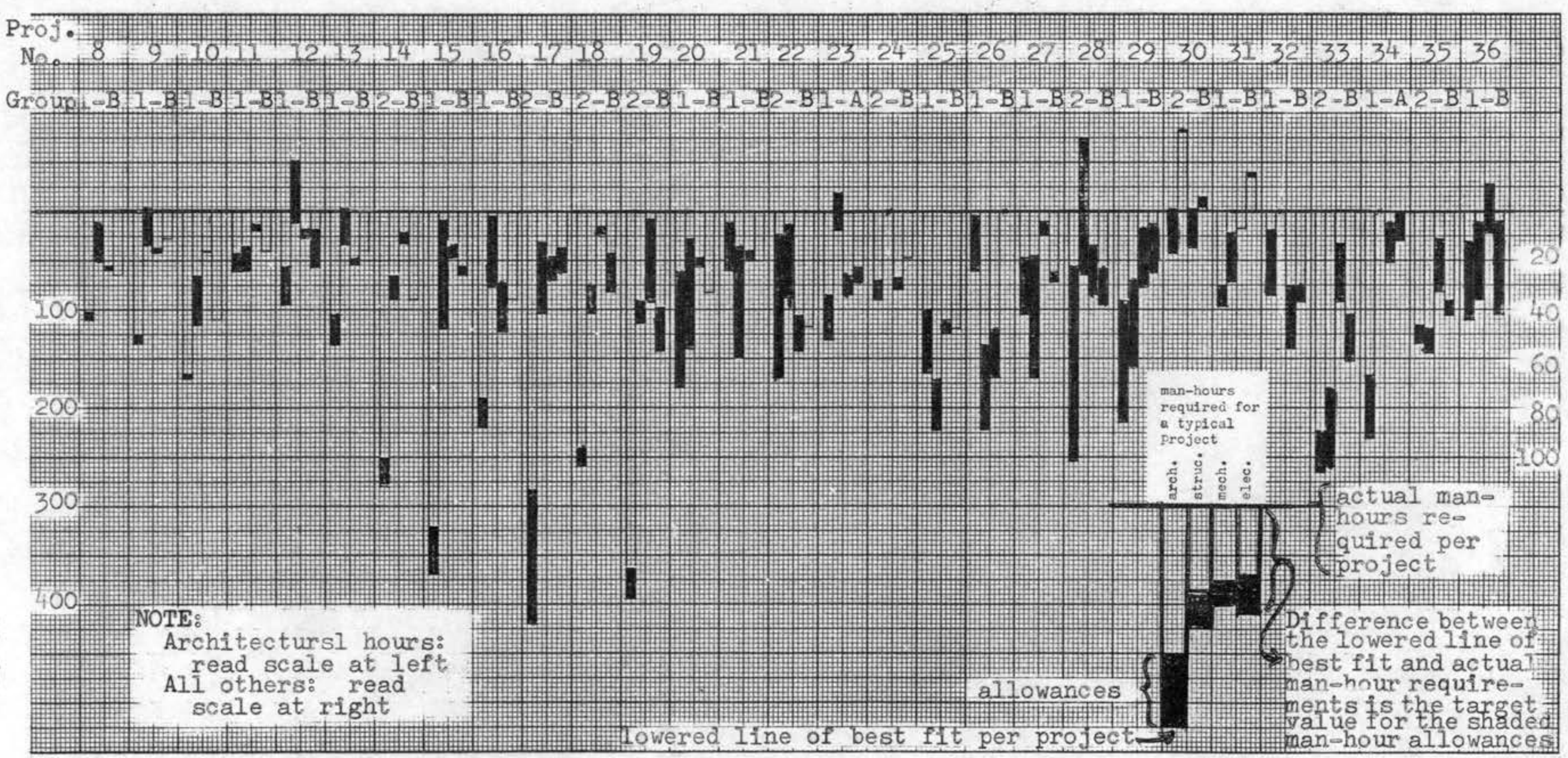



Figure 16. Effect of Man-Hour Allowances on all Projects in Study

TABLE VII

SUMMARY OF MAN-HOUR ALLOWANCES

| Item | Arch. | Struc. | Mech. | Elec. |
|---|---|---|---|---|
| CLASSIFICATION | | | | |
| 1-a | | | | |
| 1-b | | | | |
| 2-a | (160) | | | |
| 2-b | | | | |
| TYPE | | | | |
| Elem | | | | |
| Jr. Sr. H.S. | 16 | | | |
| NEW | - | | | |
| ADD'N | | | | |
| TWO STORY | 16 | | | |
| TEACH STA. | | | | |
| TOTAL ROOMS | | | | |
| SPECIAL CL. | | | | |
| Sci/Bio | 4/unit | | 2/unit | 2/unit |
| Bus/Lang | 4/unit | | | 2/unit |
| Primary | 2/unit | | 2/unit | |
| Home Ec. | 4/unit | | 2/unit | 4/unit |
| TOILETS (M) | 4/unit | | 2/unit | |
| " (S) | 4/unit | | 2/unit | |
| HOT WATER HEATING | | | 30 | 16 |
| AIR CONDITIONING | | | | |
| Spot | | | 8 | 8 |
| Central | | | 40 | 24 |
| KITCHEN | 16 | | 2 | 2 |
| CAFETORIUM | | | | |
| GYM | 8 | | 2 | 4 |
| APR | | | | 4 |
| STAGE | | | | 8 |
| SOUND/INTERCOM | | | | 16 |
| CLOCK/BELL | | | | 4(A) |
| STEEL SYS. | | 16 | | |
| P.C. JOIST ON L.B. WALLS | | 24 | | |
| P.C. COL'S AND JOISTS | | 32 | | |
| LAM. WOOD BEAMS | | 16 | | |
| DRILL PIERS | | 8 | | |
| COMPLEXITY | | | | |
| Simple | | | | |
| Average | 20 | 12 | | |
| Complex | 40 | 24 | | |
| BORROW LIGHTS | 8 | 8 | | |
| OFFICE | 4/room | | | |
| CLASSROOM LAVS: (1-4) | 1 | | 1 | |
| (5-8) | 2 | | 2 | |

(A) New School Only

NOTE: All numerals in table indicate man-hours.

## CHAPTER VII

## CONCLUSIONS AND AREAS FOR FURTHER STUDY

Figures 15 and 16 graphically demonstrate that the lowered lines of best fit plus the various man-hour allowances do not constitute a satisfactory system for estimating actual man-hour requirements on future projects. The system does reduce the difference between anticipated and actual man-hour requirements as evidenced by the shaded portions of Figures 15 and 16. However, the improvement is not sufficient to predetermine man-hour requirements before starting the preparation of plans and specifications. However, the system does serve as a starting point and may be refined with feedback from future projects. Also, it must be remembered that once the architect initiates the project, the fee is beyond his control. Adequate profit margins can be maintained only through cost control and reductions which do not affect the quality of performance. The architect depends on his reputation of performance and merely reducing productive costs at the expense of quality is probably the quickest way to realize a short-term gain with a resounding long-term loss.

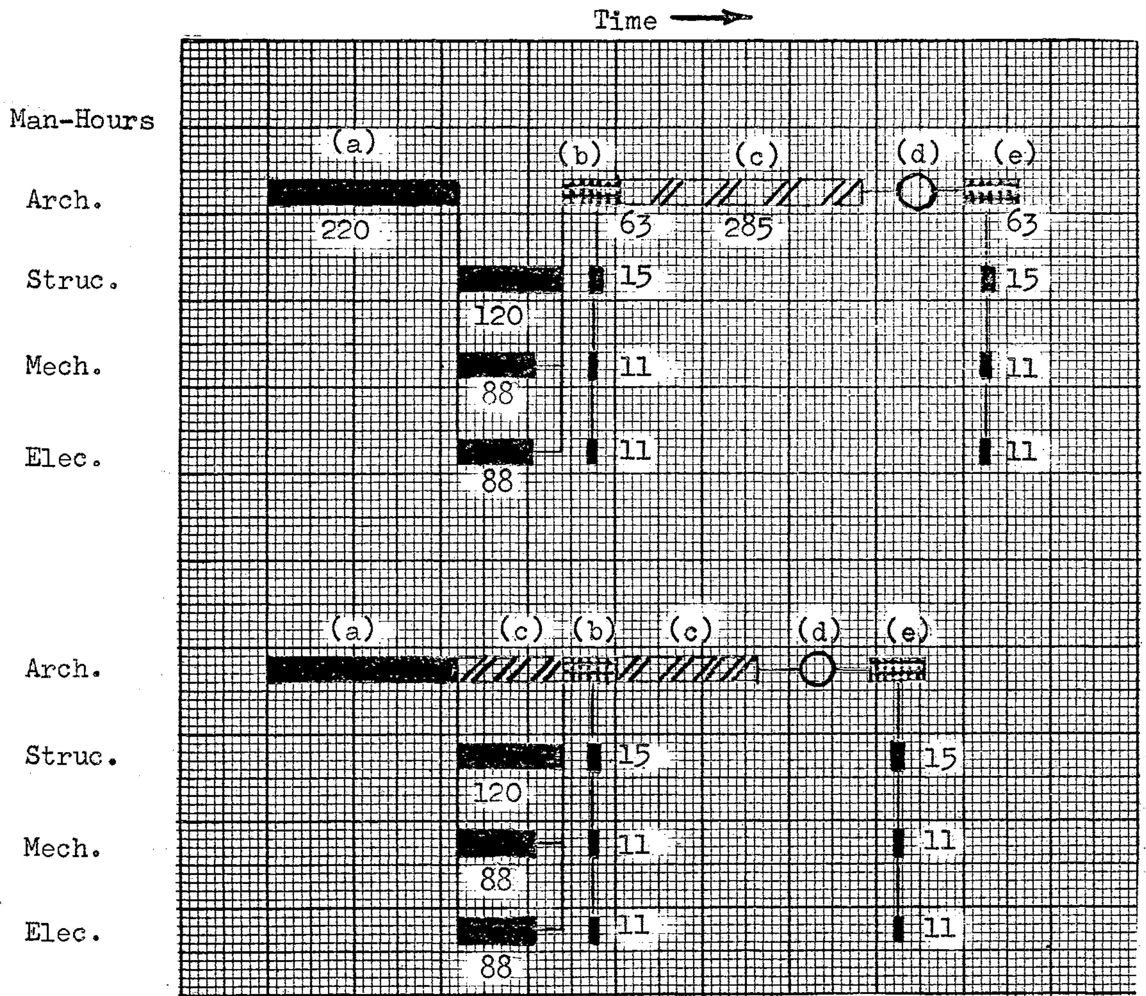
The lowered line of best fit could easily be adjusted to reflect performance on future projects. Old projects should be deleted from the calculations and the lines of best fit updated annually for all projects within a three-year span. Given enough data, it may be possible to refine the mathematical relationship between man-hours and size and, thus, express the architectural, structural, mechanical and electrical portions as a percentage of the total rather than generating a distinct line of best fit for each specialty.

The man-hour allowances will require more frequent review and revision than the lines of best fit. The presented allowances are only slightly better than educated guesses and hopefully will be refined through better record keeping on future projects. The existing system for describing each project and recording costs, although adequate for the cost accounting function, are unsatisfactory for equating production cost with project difficulty. It would be comparatively easy to devise a recording system that would ultimately establish the relationships between project complexity and the man-hours required to prepare the necessary plans. The more difficult problem is deciding whether the benefits associates with accurate man-hour forecasting would be greater than the cost of collecting the necessary data. Accurate project descriptions plus construction cost data would also be useful in planning the content of proposed projects. The man-hour data, although resulting in improved cost control, would not be particularly beneficial to the accounting function.

It may not be necessary to refine the lines of best fit and man-hour allowances at all. Acceptable results might be obtainable in practice with the basic concept of the presented system even though Figures 15 and 16 graphically demonstrate that the presented man-hour allowances do not reduce the difference between estimated and actual man-hour requirements to acceptable limits. However, the existing system attempts to predict the total number of man-hours required for each specialty to prepare the plans <u>before</u> the plans are even started.

The man-hour estimates could be revised weekly to reflect progress to date. Weekly forecasts would mean that the man-hour forecasts would become more accurate as the project neared completion. The utility of advanced knowledge as to man-hour requirements is virtually limited to scheduling, since the work will proceed even if the cost of the estimated man-hours exceeds the anticipated fee. The existing system could in all probability be used as is providing the man-hour forecasts were revised weekly in accordance with the previous week's performance.

Figure 17 depicts scheduling of a hypothetical project requiring 1000 man-hours to prepare the plans. Each project starts with a planning conference which outlines the project stating size, materials, configuration, number and type of rooms and all other information necessary to prepare working drawings. The architectural department initiates the drawings and starts the site and floor plans. These two plans are required before the structural, mechanical, and electrical departments can even start their portion of the drawings. Once the site and floor plans are completed, the architectural department may work on other projects or, as shown in the lower portion of Figure 17, proceed with the necessary elevations, details and schedules which may be drawn independently of the other departments. The mechanical and electrical departments will cross check their plans before sending the drawing, along with the structural plans, back to the architectural department for coordination. There are bound to be some contradictions between the respective plans, duct work through structural members for instance, and the architectural department is responsible to rectify such inconsistencies and obtain a compatible set of drawings. The architectural department completes the remaining details and releases the plans to




NOTES:

1. a ≡ site and floor plans
   b ≡ coordination
   c ≡ elevations and dtls
   d ≡ check
   e ≡ correct and coordinate

2. Numerals beneath each bar indicate man-hours

3. Total man-hour requirements:

| | |
|---|---|
| Arch. | 630 |
| Struc. | 150 |
| Mech. | 110 |
| Elec. | 110 |
| | 1000 |

Figure 17. Scheduling a Typical Project

another department that is responsible for checking both the plans and the specifications. The architectural department is responsible for coordinating all of the corrections required after the final check. The plans are now ready for issuing to the contractors. The foregoing is a super-simplified description of the process. Such things as the preparation of specifications and in progress reviews by the client have been omitted.

Note that in Figure 17, the 630 architectural man-hours determine the completion date of the plans. Normally, a project of this size would require the efforts of three architectural draftsmen. At 40 hours per week per architect, the 630 man-hour project would require approximately 5.25 weeks to complete the plans. The duration of this project would consequently allow five revisions of the initial man-hour forecast. Certainly, the accuracy of these successive revisions should increase as the plans approach completion.

# APPENDIX

A- 1 Project Summary Sheet: Used in initial portion of investigation. Discarded after study was confined to the design phase of each project and because of insufficient room to describe the project.

Least Square Calculations: Shows line of best fit and lowered line of best fit for:

A- 2 Total Man-Hour Requirements.

A- 3 Architectural Man-Hour Requirements.

A- 4 Structural Man-Hour Requirements.

A- 5 Mechanical Man-Hour Requirements.

A- 6 Electrical Man-Hour Requirements.

Graphs of basic data and lines of best fit for:

A- 7 Structural Man-Hour Requirements.

A- 8 Mechanical Man-Hour Requirements.

A- 9 Electrical Man-Hour Requirements.

Graphs of lowered lines of best fit for:

A-10 Structural Man-Hour Requirements.

A-11 Mechanical Man-Hour Requirements.

A-12 Electrical Man-Hour Requirements.

Tables of the man-hours deviation between the lowered line of best fit and actual man-hour requirements on each project for:

A-13 Architectural and Structural Man-Hour Requirements

A-14 Mechanical and Electrical Man-Hour Requirements

Project descriptions used in final phases of study used in determining allowances for:

A-15 Structural Features.

A-16 Mechanical Features.

A-17 Electrical Features.

Man-Hour allowances in same format as project descriptions for:

A-18 Structural Man-Hour Requirements

A-19 Mechanical Man-Hour Requirements

A-20 Electrical Man-Hour Requirements

APPENDIX A-1

PROJECT SUMMARY SHEET

Project

Project Description

Site

Below Grade

Floors

Exterior Walls

Interior Walls

Ceiling

Roof

Heating

Electrical

Miscellaneous

Construction Cost

| | DESIGN | | | | CONSTRUCTION | | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $ | % | Hrs. | % | $ | % | Hrs. | % | $ | % | Hrs. | % |
| Arch. | | | | | | | | | | | | |
| Struc. | | | | | | | | | | | | |
| Mech. | | | | | | | | | | | | |
| Elec. | | | | | | | | | | | | |
| Spec. | | | | | | | | | | | | |
| Repro. | | | | | | | | | | | | |
| Surv. | | | | | | | | | | | | |
| Civil | | | | | | | | | | | | |
| Supv. | | | | | | | | | | | | |
| To'. | | | | | | | | | | | | |

Design Cost from Curve: Dev.

| | Curve $ | Av. % | | $ | App. Diff. | Est. Diff. | Adj. $ |
|---|---|---|---|---|---|---|---|
| Architectural | | | | | | | |
| Structural | | | | | | | |
| Mechanical | | | | | | | |
| Electrical | | | | | | | |
| Specifications | | | | | | | |
| Reproduction | | | | | | | |
| Survey | | | | | | | |
| Civil | | | | | | | |
| Supervision | | | | | | | |
| TOTAL | | | | | | | |

REMARKS:

APPENDIX A-2

STRAIGHT LINE OF BEST FIT FOR

TOTAL MAN-HOUR REQUIREMENTS

BY $Y = b_o + (b_1)x$

WHERE x IS IN SQUARE FEET

AND y IS IN MAN-HOURS

TOTAL MAN-HOUR REQUIREMENTS

| Group | x(S.F.) | y(M.H.) | $(x)^2$ | xy | N |
|---|---|---|---|---|---|
| 2 | 37,050 | 1,693 | 196,297,662 | 10,286,798 | 7 |
| 3 | 41,713 | 3,045 | 292,701,241 | 21,202,463 | 6 |
| 4 | 57,169 | 2,865 | 548,963,029 | 27,446,148 | 6 |
| 5 | 76,450 | 3,738 | 979,179,890 | 46,981,737 | 6 |
| 6 | 150,637 | 5,920 | 4,094,996,937 | 155,689,319 | 6 |
| Total | 363,019 | 17,261 | 6,110,138,759 | 261,606,465 | 31 |

$$b_o = [(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)]/d$$

$$= [(17,261)(6,110,138,759) - (363,019)(261,606,465)]/d$$

$$= 1.050 \times 10^{13}$$

$$b_1 = [(N)(\Sigma XY) - (\Sigma X)(\Sigma Y)]/d = [(31)(261,606,465) - (363,019)(17,261)]/d$$

$$= 1.844 \times 10^9$$

$$d = N(\Sigma X^2) - (\Sigma X)^2 = (31)(6,110,138,759) - (363,019)^2$$

$$= 5.76 \times 10^{10}$$

$$b_o = \frac{1.050}{5.76} \ \frac{10^{13}}{10^{10}} = .1823 \times 10^3 = 182$$

$$b_1 = \frac{1.844}{5.76} \ \frac{10^9}{10^{10}} = .320 \times 10^{-1} = .032$$

$$Y = b_o + (b_1)X = 182 + (.032)x$$

APPENDIX A-3

STRAIGHT LINE OF BEST FIT FOR

ARCHITECTURAL MAN-HOUR REQUIREMENTS

BY $Y = b_o + (b_1)x$

WHERE x IS IN SQUARE FEET AND y

IS IN MAN-HOURS

ARCHITECTURAL MAN-HOUR REQUIREMENTS

| Group | x(S.F.) | y(M.H.) | $(x)^2$ | xy | N |
|---|---|---|---|---|---|
| 2 | 37,050 | 1,150 | 196,297,662 | 6,127,943 | 7 |
| 3 | 41,713 | 2,181 | 292,701,241 | 15,148,922 | 6 |
| 4 | 77,625 | 2,155 | 758,495,895 | 20,983,324 | 8 |
| 5 | 76,450 | 2,073 | 979,179,890 | 26,305,688 | 6 |
| 6 | 189,071 | 4,657 | 4,868,342,237 | 116,893,823 | 8 |
| Totals | 421,909 | 12,216 | 7,095,016,925 | 185,459,700 | 35 |

$$b_o = [(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)]/d$$

$$= [(12,216)(7,095,016,925) - (421,909)(185,459,700)]/d$$

$$= [(8.4256)(10)^{12}]/d$$

$$b_1 = [(N)(\Sigma XY) - (\Sigma X)(\Sigma Y)]/d$$

$$= [(35)(185,459,700) - (421,909)(12,216)]/d$$

$$= [(1.337)(10)^9]/d$$

$$d = (N)(\Sigma X^2) - (\Sigma X)^2 = (35)(7,095,016,925) - (421,909)^2$$

$$= (7.0318)(10)^{10}$$

$$b_o = [(8.4256)(10)^{12}]/(7.0318)(10)^{10} = 119.8 \qquad \text{(use 120)}$$

$$b_1 = [(1.337)(10)^9]/(7.0318)(10)^{10} = .01901 \qquad \text{(use .019)}$$

$$Y = b_o + (b_1)X = 120 + (.019)X$$

Lower line of best fit so that line intercepts x-axis at 4000 S.F.: $Y = 120 + (.019)X$

$$Y = 120 + (.019)(4000) = 120 + 76 = 196$$

then $Y = (120 - 196) + (.019)X$

and lowered line of best fit is determined by:

$$Y = -76 + (.019)X$$

APPENDIX A-4

STRAIGHT LINE OF BEST FIT FOR

STRUCTURAL MAN-HOUR REQUIREMENTS

BY $Y = b_o + (b_1)x$

WHERE x IS IN SQUARE FEET AND

y IS IN MAN-HOURS

STRUCTURAL MAN-HOUR REQUIREMENTS

| Group | x(S.F.) | y(M.H.) | $(x)^2$ | xy | N |
|---|---|---|---|---|---|
| 2 | 37,050 | 201 | 196,297,662 | 1,064,165 | 7 |
| 3 | 41,713 | 354 | 292,701,241 | 2,491,853 | 6 |
| 4 | 67,790 | 608 | 661,768,670 | 6,000,367 | 7 |
| 5 | 76,450 | 524 | 979,179,890 | 6,713,538 | 6 |
| 6 | 150,637 | 845 | 4,094,996,937 | 22,650,001 | 6 |
| Total | 373,640 | 2,532 | 6,224,944,400 | 38,919,924 | 32 |

$$b_o = [(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)]/d$$
$$= [(2532)(6,224,944,400) - (373,640)(38,919,924)]/d$$
$$= 1.2195 \times 10^{12}/d$$

$$b_1 = [(N)(\Sigma XY) - (\Sigma X)(\Sigma Y)]/d = [(32)(38,919,924) - (373,640)(2532)]/d$$
$$= 2.9938 \times 10^{8}/d$$

$$d = N(\Sigma X^2) - (\Sigma X)^2 = 32(6,224,944,400) - (373,640)^2$$
$$= 5.9591 \times 10^{10}$$

$$b_o = \left(\frac{1.2195}{5.9591}\right) \cdot \left(\frac{10^{12}}{10^{10}}\right) = .2046 \times 10^2 = 20$$

$$b_1 = \left(\frac{2.9938}{5.9591}\right) \cdot \left(\frac{10^{8}}{10^{10}}\right) = .5024 \times 10^{-2} = .005$$

$$Y = b_o + b_1(X) = 20 + (.005)X$$

Lower line of best fit so that line intercepts x-axis at

4000 SF: $Y = 20 + (.005)x$

$$Y = 20 + (.003)(4000) = 20 + 20 = 40$$

then $Y = (20 - 40) + (.005)x$

and the lowered line of best fit is determined by:

$$Y = -20 + (.005)x.$$

## APPENDIX A-5

STRAIGHT LINE OF BEST FIT FOR

MECHANICAL MAN-HOUR REQUIREMENTS

BY $Y = b_o + (b_1)x$

WHERE x IS IN SQUARE FEET AND

y IS IN MAN-HOURS

MECHANICAL MAN-HOUR REQUIREMENT

| Group | x(S.F.) | y(M.H.) | $(x)^2$ | xy | N |
|---|---|---|---|---|---|
| 2 | 37,050 | 128 | 196,297,662 | 676,515 | 7 |
| 3 | 41,713 | 214 | 292,701,241 | 1,482,224 | 6 |
| 4 | 67,790 | 418 | 661,768,670 | 4,004,777 | 7 |
| 5 | 76,450 | 406 | 979,179,890 | 5,193,752 | 6 |
| 6 | 189,071 | 784 | 4,868,342,237 | 19,841,500 | 8 |
| Total | 412,074 | 1,950 | 6,998,289,700 | 31,198,768 | 34 |

$$b_o = [(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)]/d$$

$$= [(1950)(6,998,289,700) - (412,074)(31,198,768)]/d$$

$$= (7.905 \times 10^{11})/d$$

$$b_1 = [(N)(\Sigma XY) - (\Sigma X)(\Sigma Y)]/d$$

$$= [(34)(31,198,768) - (412,074)(1,950)]/d$$

$$= (2.5721 \times 10^8)/d$$

$$d = (N)(\Sigma X^2) - (\Sigma X)^2 = (34)(6.998,289,700) - (412,074)$$

$$= 6.8134 \times 10^{10}$$

$$b_o = \left(\frac{7.905}{6.8134}\right)\left(\frac{10^{11}}{10^{10}}\right) = 1.160 \times 10^1 = 12$$

$$b_1 = \left(\frac{2.5721}{6.8134}\right)\left(\frac{10^8}{10^{10}}\right) = .378 \times 10^{-2} = .00378$$

$$Y = b_o + b_1 x = 12 + (.00378)X = 12 + (.00378)x$$

Lower line of best fit so that line intercepts x-axis at

4000 S.F.: $Y = 12 + (.00378)x$

$$Y = 12 + (.00378)(4000) = 12 + 15 = 27$$

then $Y = (12 - 27) + (.00378)x$

and the lowered line of best fit is determined by:

$$Y = -15 + (.00378)x$$

APPENDIX A-6

STRAIGHT LINE OF BEST FIT FOR

ELECTRICAL MAN-HOUR REQUIREMENTS

BY $Y = b_o + (b_1)x$

WHERE x IS IN SQUARE FEET AND

y IS IN MAN-HOURS

ELECTRICAL MAN-HOUR REQUIREMENTS

| Group | $\Sigma X$ | $\Sigma Y$ | $\Sigma X^2$ | $\Sigma XY$ | N |
|---|---|---|---|---|---|
| 1 | 27,102 | 188 | 109,510,700 | 762,487 | 7 |
| 2 | 37,050 | 208 | 196,297,662 | 1,102,045 | 7 |
| 3 | 41,713 | 277 | 292,701,241 | 1,953,180 | 6 |
| 4 | 77,625 | 471 | 758,495,895 | 4,592,852 | 8 |
| 5 | 76,450 | 375 | 979,179,890 | 4,773,359 | 6 |
| 6 | 189,071 | 813 | 4,868,342,237 | 20,032,268 | 8 |
| Grand Total | 449,011 | 2,332 | 7,204,527,625 | 33,216,191 | 42 |
| SS(w/o G. No. 1) | 421,909 | 2,144 | 7,095,016,925 | 32,453,704 | 35 |

$$b_o = [(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)]/d$$

$$= [(2,332)(7,204,527,625) - (449,011)(33,216,191)]/d$$

$$= 1.886 \times 10^{12}/d$$

$$b_1 = [(N)(\Sigma XY) - (\Sigma X)(\Sigma Y)]/d = [(42)(33,216,191) - (449,011)(2,332)]$$

$$= 3.619 \times 10^{8}/d$$

$$d = N(\Sigma X^2) - (\Sigma X)^2 = (42)(7,204,527,625) - (449,011)^2$$

$$= 1.01 \times 10^{11}$$

$$b_o = \frac{1.886}{1.01} \times \frac{10^{12}}{10^{11}} = 1.867 \times 10^{11} = 18.67$$

$$b_1 = \frac{3.619}{1.01} \times \frac{10^{8}}{10^{11}} = 3.583 \times 10^{-3} = .00358$$

$$Y = b_o + (b_1)X = 18.67 + (.00358)X$$

at X = 0 Y = 19

at X = 5,000 SF Y = 18.67 + 17.9 = 36.57 or 37.

at X = 10,000 SF Y = 18.67 + 35.8 = 54.47 or 54.

at X = 20,000 SF Y = 18.67 71.6 = 90.27 or 90.

Same problem omitting group 1 (< 5,000 SF)

ELECTRICAL (Continued)

$$b_o = [(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)]/d$$

$$= [(2,144)(7,095,016,925) - (421,909)(32,453,704)$$

$$= 1.519 \times 10^{12}/d$$

$$b_1 = [(N)(\Sigma XY) - (\Sigma X)(\Sigma Y)]/d = (35)(32,453,704) - (421,909)(2,144)$$

$$= 2.461 \times 10^8/d$$

$$d = (N)(\Sigma X^2) - (\Sigma X)^2 = (35)(7,095,016,925) - (421,909)^2 = 7.032 \times 10^{10}$$

$$b_o = \frac{1.519}{7.032} \cdot \frac{10^{12}}{10^{10}} = 2.16 \times 10^1 = 21.6$$

$$b_1 = \frac{2.461}{7.032} \quad \frac{10^8}{10^{10}} = 3.50 \times 10^{-3} = .0035$$

$$Y = b_o + (b_1)X = 21.6 + (.0035)x$$

Lower line of best fit so that line intercepts x-axis at

4000 S.F.: $Y = 21.6 + (.0035)x$

$$Y = 21.6 + (.0035)(4000) = 21.6 + 16 = 37.6$$

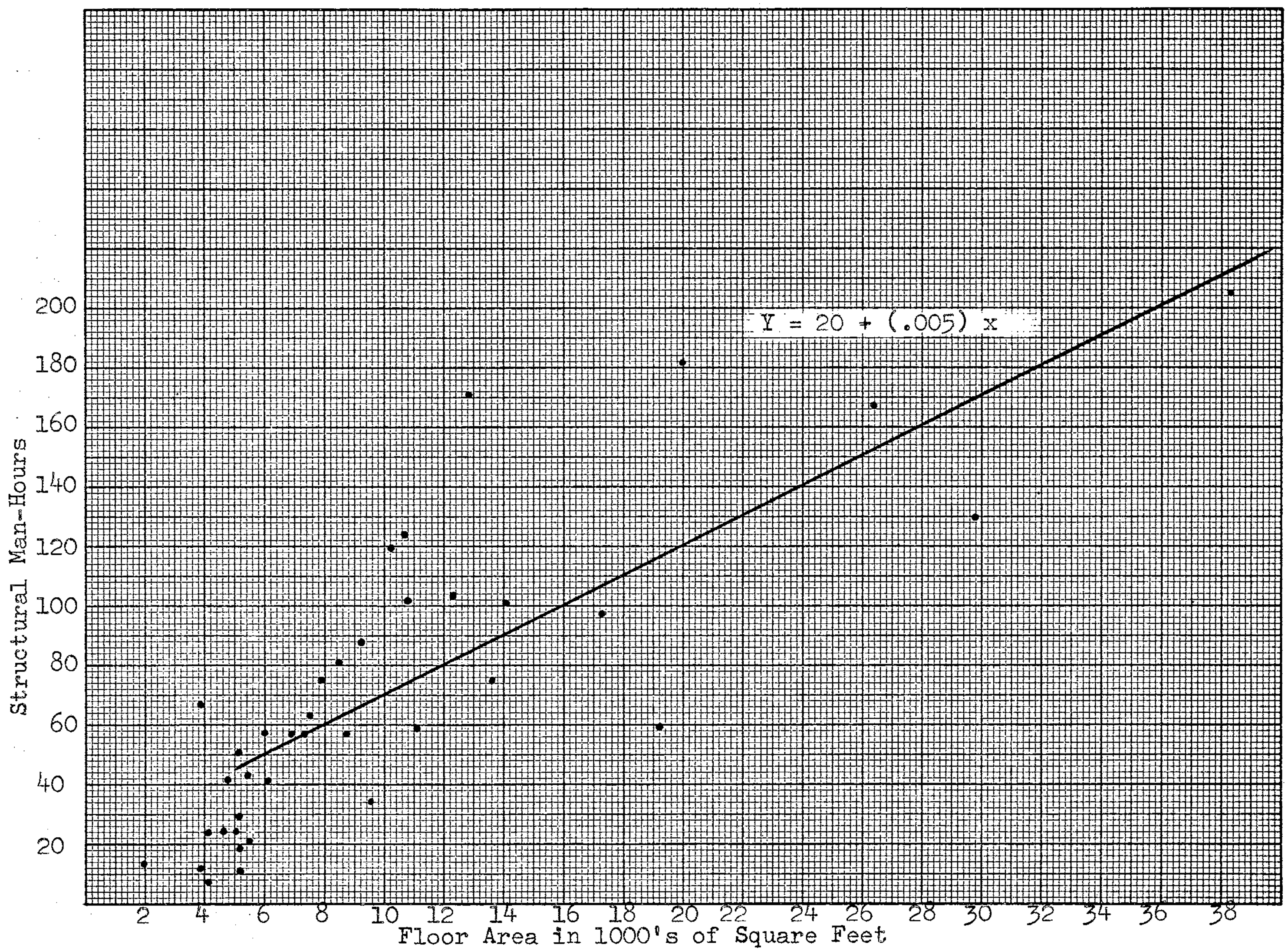
then $Y = (21.6 - 37.6) + (.0035)x$

and lowered line of best fit is determined by:

$$Y = -16 + (.0035)x.$$

APPENDIX A-7

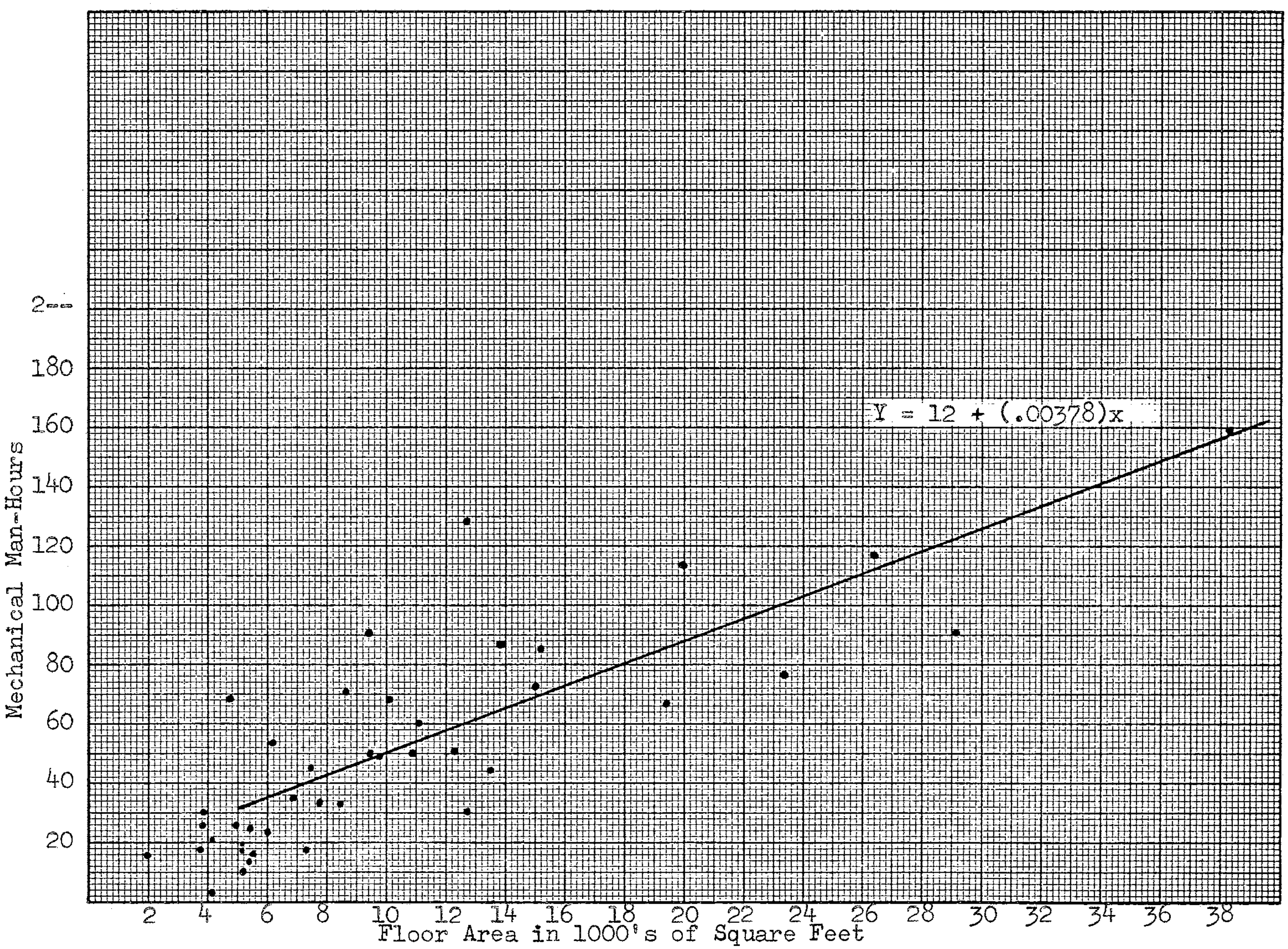
STRUCTURAL MAN-HOUR REQUIREMENTS



Y = 20 + (.005) x
Structural Man-Hours
200
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Floor Area in 1000's of Square Feet

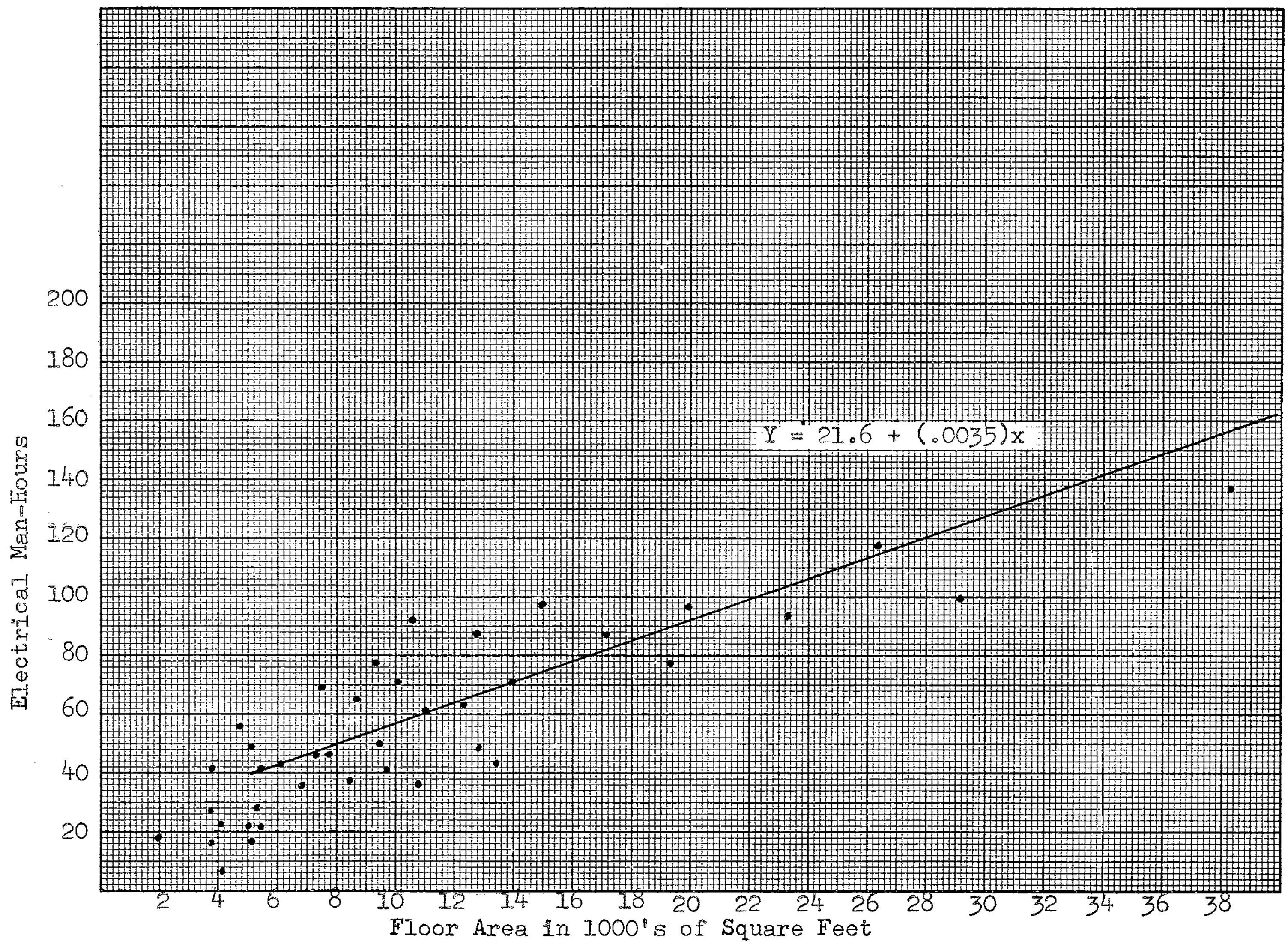
APPENDIX A-8

MECHANICAL MAN-HOUR REQUIREMENTS


Y = 12 + (.00378)x
Mechanical Man-Hours
2--
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Floor Area in 1000's of Square Feet

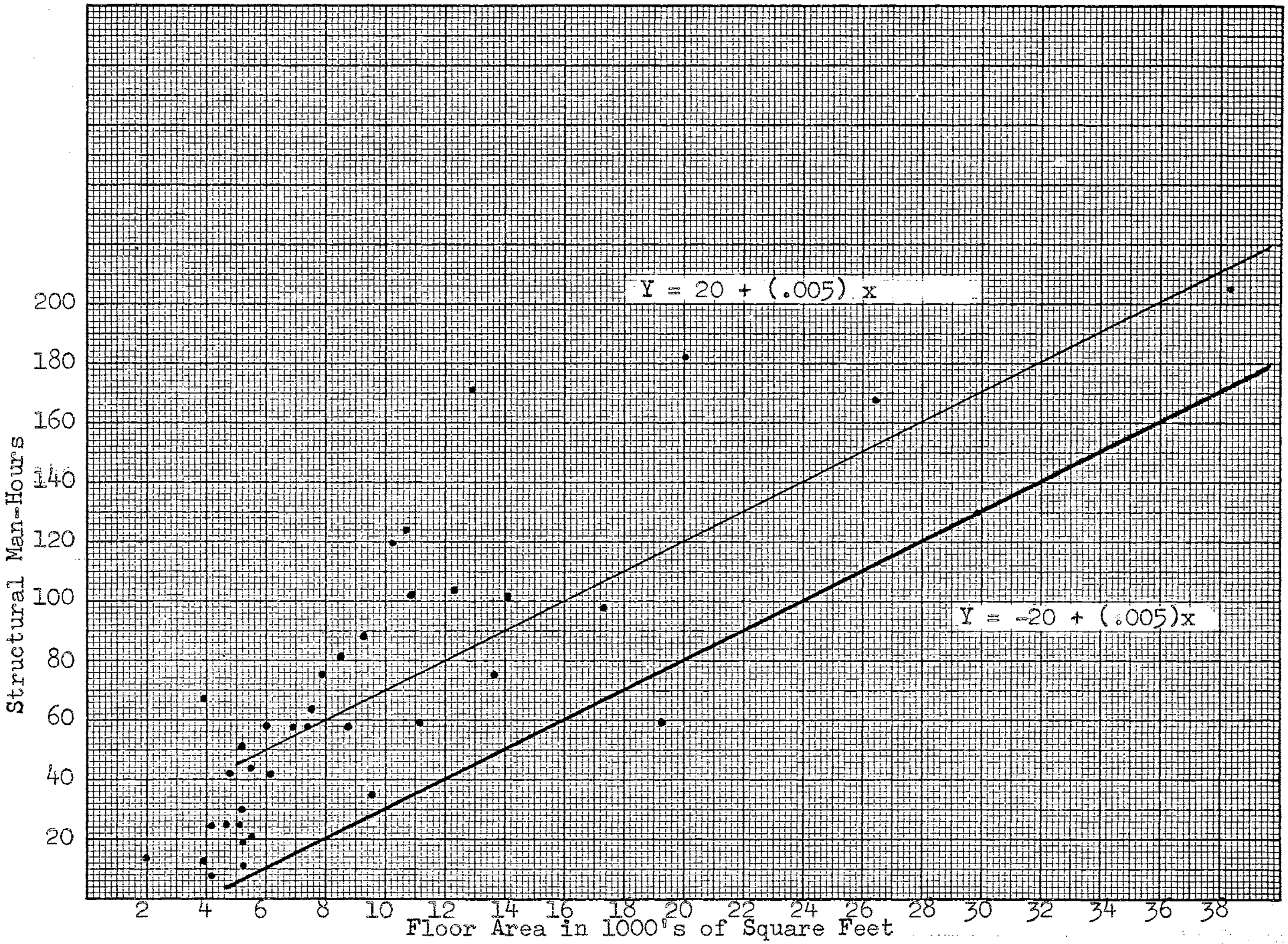
APPENDIX A-9

ELECTRICAL MAN-HOUR REQUIREMENTS


Y = 21.6 + (.0035)x
Electrical Man-Hours
200
180
160
140
120
100
80
60
40
20
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
Floor Area in 1000's of Square Feet

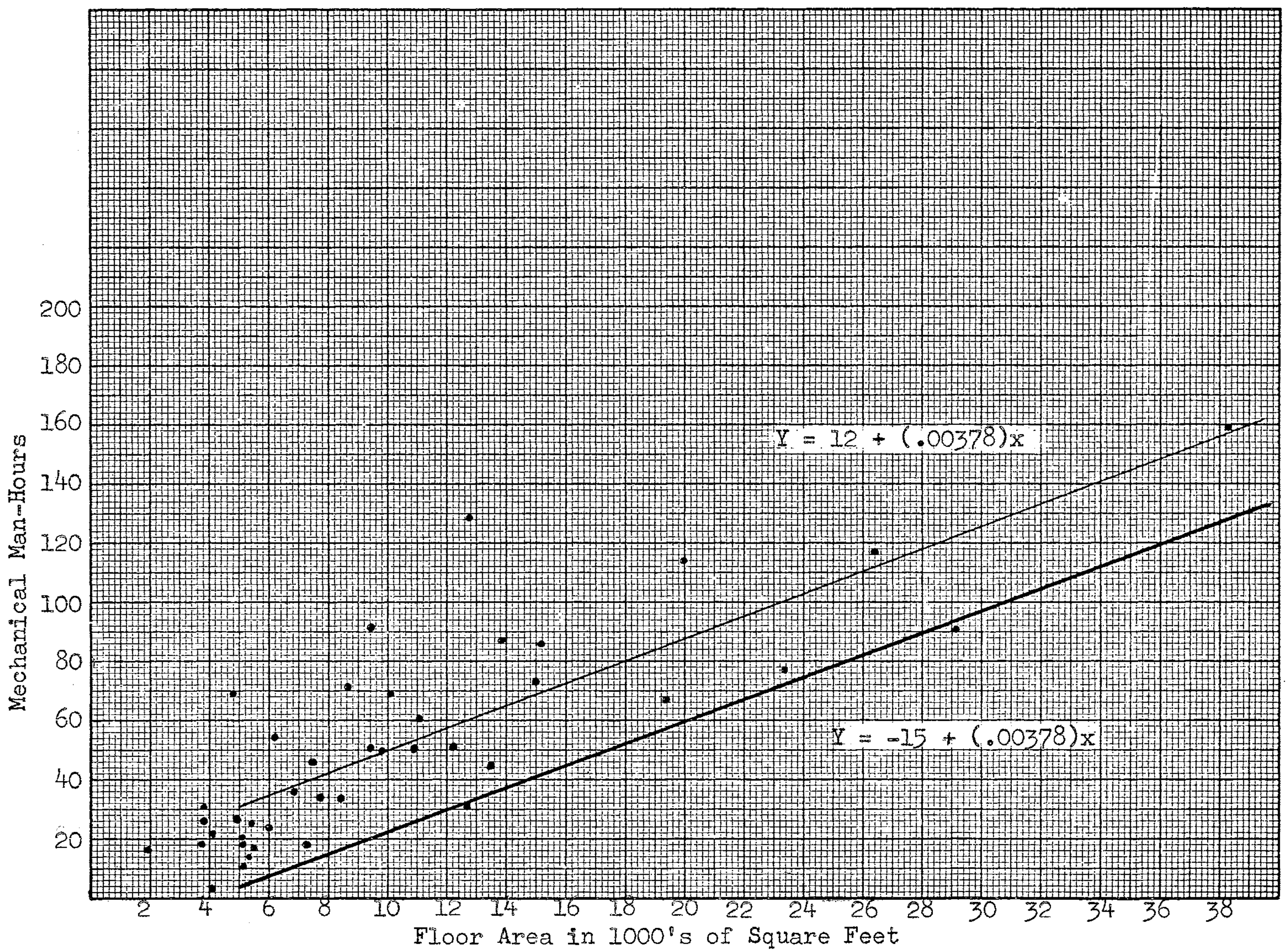
# APPENDIX A-10

## STRUCTURAL MAN-HOUR REQUIREMENTS


Y = 20 + (.005) x
Y = -20 + (.005)x
Structural Man-Hours
200
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Floor Area in 1000's of Square Feet

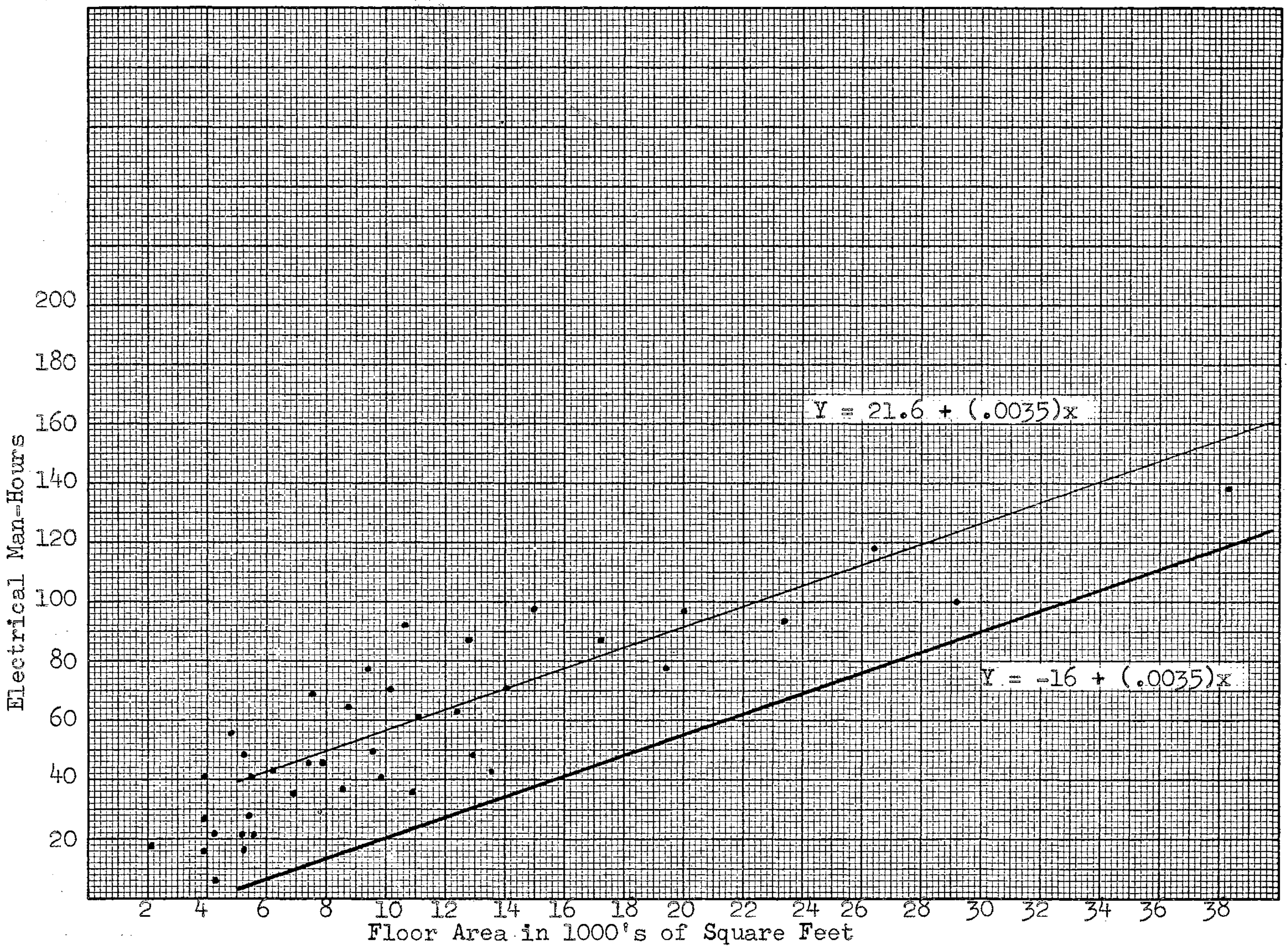
APPENDIX A-11

MECHANICAL MAN-HOUR REQUIREMENTS


Mechanical Man-Hours
200
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Floor Area in 1000's of Square Feet
Y = 12 + (.00378)x
Y = -15 + (.00378)x

APPENDIX A-12

ELECTRICAL MAN-HOUR REQUIREMENTS


Y = 21.6 + (.0035)x
Y = -16 + (.0035)x
Electrical Man-Hours
200
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Floor Area in 1000's of Square Feet

APPENDIX A-13

ARCHITECTURAL AND STRUCTURAL MAN-HOUR REQUIREMENTS

SUMMARY OF MAN-HOUR DEVIATIONS BETWEEN THE LOWERED LINE OF BEST FIT AND ACTUAL PERFORMANCE FOR ARCHITECTURAL AND STRUCTURAL MAN-HOUR REQUIREMENTS

| Proj. No. | Floor area in S.F. | Architectural Man-Hours Act. | Architectural Man-Hours Base | Architectural Man-Hours Dev. | Structural Man-Hours Act. | Structural Man-Hours Base | Structural Man-Hours Dev. |
|---|---|---|---|---|---|---|---|
| 8 | 5,034 | 127 | 20 | 107 | 24 | 5 | 19 |
| 9 | 5,178 | 158 | 22 | 136 | 19 | 6 | 13 |
| 10 | 5,198 | 191 | 23 | 168 | 52 | 6 | 46 |
| 11 | 5,233 | 83 | 23 | 60 | 30 | 6 | 24 |
| 12 | 5,378 | 119 | 26 | 93 | 11 | 7 | 4 |
| 13 | 5,511 | 162 | 29 | 133 | 21 | 8 | 13 |
| 14 | 5,518 | 310 | 29 | 281 | 44 | 8 | 36 |
| 15 | 6,020 | 407 | 38 | 369 | 58 | 10 | 48 |
| 16 | 6,140 | 260 | 41 | 219 | 42 | 11 | 31 |
| 17 | 6,909 | 474 | 55 | 419 | 57 | 15 | 42 |
| 18 | 7,336 | 323 | 63 | 260 | 58 | 17 | 41 |
| 19 | 7,508 | 461 | 70 | 391 | 64 | 18 | 46 |
| 20 | 7,800 | 256 | 75 | 181 | 75 | 19 | 56 |
| 21 | 8,460 | 145 | 85 | 60 | 81 | 22 | 59 |
| 22 | 8,698 | 256 | 89 | 167 | 58 | 23 | 35 |
| 23 | 9,412 | 516 | 103 | 413 | 89 | 27 | 62 |
| 24 | 9,511 | 233 | 105 | 128 | 35 | 28 | 7 |
| *25 | 9,835 | 201 | 111 | 90 | - | 29 | |
| 26 | 10,132 | 282 | 117 | 165 | 120 | 31 | 89 |
| *27 | 10,621 | 286 | 126 | 60 | 122 | 33 | 89 |
| 28 | 10,956 | 236 | 132 | 104 | 103 | 35 | 68 |
| 29 | 11,090 | 414 | 135 | 279 | 60 | 35 | 25 |
| 30 | 12,259 | 372 | 157 | 215 | 104 | 41 | 63 |
| 31 | 12,752 | 385 | 166 | 219 | 172 | 44 | 128 |
| 32 | 12,856 | 208 | 168 | 40 | 10 | 44 | -34 |
| 33 | 13,538 | 274 | 181 | 93 | 76 | 48 | 28 |
| 34 | 13,955 | 420 | 189 | 231 | 102 | 50 | 52 |
| *35 | 15,048 | 296 | 210 | 86 | SUL | 55 | |
| 36 | 17,233 | 615 | 251 | 364 | 98 | 66 | 32 |
| 37 | 19,399 | 472 | 293 | 179 | 60 | 77 | -17 |
| 38 | 20,035 | 572 | 305 | 267 | 183 | 80 | 103 |
| *39 | 23,386 | 598 | 368 | 230 | SUL | 97 | |
| 40 | 26,431 | 559 | 426 | 133 | 168 | 111 | 57 |
| 41 | 29,245 | 830 | 480 | 350 | 130 | 126 | 4 |
| 42 | 38,294 | 760 | 652 | 108 | 206 | 171 | 35 |

APPENDIX A-14

MECHANICAL AND ELECTRICAL MAN-HOUR REQUIREMENTS

SUMMARY OF MAN-HOUR DEVIATIONS BETWEEN THE LOWERED LINE OF BEST FIT AND ACTUAL PERFORMANCE FOR MECHANICAL AND ELECTRICAL MAN-HOUR REQUIREMENTS

| Proj. No. | Floor are in S.F. | Mechanical Man-Hours Act. | Mechanical Man-Hours Base | Mechanical Man-Hours Dev. | Electrical Man-Hours Act. | Electrical Man-Hours Base | Electrical Man-Hours Dev. |
|---|---|---|---|---|---|---|---|
| 8 | 5,034 | 26 | 2 | 24 | 30 | 4 | 26 |
| 9 | 5,178 | 19 | 2 | 17 | 16 | 5 | 11 |
| 10 | 5,179 | 18 | 2 | 16 | 49 | 5 | 44 |
| 11 | 5,233 | 10 | 2 | 8 | 21 | 5 | 16 |
| 12 | 5,378 | 14 | 3 | 11 | 28 | 5 | 23 |
| 13 | 5,511 | 25 | 3 | 22 | 22 | 6 | 16 |
| 14 | 5,518 | 16 | 3 | 13 | 42 | 6 | 36 |
| 15 | 6,020 | 24 | 5 | 19 | 34 | 8 | 26 |
| 16 | 6,140 | 54 | 5 | 49 | 44 | 8 | 36 |
| 17 | 6,909 | 36 | 8 | 28 | 36 | 11 | 25 |
| 18 | 7,336 | 19 | 10 | 9 | 46 | 13 | 33 |
| 19 | 7,508 | 47 | 10 | 37 | 70 | 13 | 57 |
| 20 | 7,800 | 34 | 11 | 23 | 47 | 14 | 33 |
| 21 | 8,460 | 34 | 14 | 20 | 37 | 17 | 20 |
| 22 | 8,698 | 71 | 14 | 57 | 65 | 18 | 47 |
| 23 | 9,412 | 92 | 17 | 75 | 78 | 21 | 57 |
| 24 | 9,511 | 51 | 17 | 34 | 50 | 21 | 29 |
| 25 | 9,835 | 50 | 18 | 32 | 41 | 22 | 19 |
| 26 | 10,132 | 69 | 19 | 50 | 71 | 23 | 48 |
| 27 | 10,621 | * | 21 | | 93 | 25 | 68 |
| 28 | 10,956 | 51 | 22 | 29 | 36 | 26 | 10 |
| 29 | 11,090 | 61 | 23 | 38 | 61 | 27 | 34 |
| 30 | 12,259 | 52 | 27 | 25 | 62 | 31 | 31 |
| 31 | 12,752 | 129 | 29 | 100 | 89 | 33 | 56 |
| 32 | 12,856 | 31 | 29 | -2 | 49 | 34 | 15 |
| 33 | 13,538 | 45 | 31 | -14 | 43 | 36 | 7 |
| 34 | 13,955 | 88 | 33 | 55 | 71 | 38 | 33 |
| 35 | 15,048 | 74 | 37 | 37 | 98 | 42 | 56 |
| 36 | 17,233 | 86 | 45 | 41 | 88 | 50 | 38 |
| 37 | 19,399 | 61 | 52 | 9 | 78 | 58 | 20 |
| 38 | 20,035 | 115 | 54 | 61 | 98 | 61 | 37 |
| 39 | 23,386 | 78 | 66 | 12 | 94 | 73 | 21 |
| 40 | 26,431 | 118 | 76 | 42 | 118 | 85 | 33 |
| 41 | 29,245 | 92 | 86 | 6 | 100 | 96 | 4 |
| 42 | 38,294 | 160 | 118 | 42 | 139 | 130 | 9 |

APPENDIX A-15

STRUCTURAL FEATURES

## PROJECT DESCRIPTIONS: STRUCTURAL FEATURES

NOTE: The standard of base structure has 1'-1" exterior load bearing walls on drill piers. The roof is built-up on a metal deck and supported by bar joists. This summary is on an exception criteria: only features that are an addition or supercede items in the standard description are tabulated and are designated with an "X".

| Project Number | Structural Steel System | Concrete Joists | Concrete Columns and Joists. Non-Load Bearing Walls on First Floor | Borrow Lights | Laminated Beams | Piers or Spot Footings | Two Story | Addition | | New | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Ave | Complex | | |
| 8 | | | | x | | | | | | | |
| 9 | | | | x | | | | x | | | |
| 10 | | | | | x | | | x | | | |
| 11 | | | | | | | | | | | |
| 12 | | | | x | | | | | | | |
| 13 | | | | x | | (1) | | | | | |
| 14 | | | | | | | | | | | |
| 15 | | | x | | | | x | | | | |
| 16 | | | | | x | | | x | | | |
| 17 | | | | | | | | x | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | x | | | | x | | | | |
| 21 | | | x | | | | x | | | | |
| 22 | | | | | | | | | x | | |
| 23 | | | | | | | | | | x | |
| 24 | | | | x | | | | | | x | |
| 25 | | | | | | | | | | | |
| 26 | | | | | x | | x | | x | | |
| 27 | | x | | | | | x | | | | |
| 28 | | | x | | | | x | | | | |
| 29 | x | | | x | | | | | x | | |
| 30 | | x | | | | | | | | | |

| Project Number | Structural Steel System | Concrete Joists | Concrete Columns and Joists. Non-Load Bearing Walls | Borrow lights | Laminated Beams | Piers or Spot Footings | Two Story | Addition Ave | Addition Complex | New | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | | | | | | | | | | x | |
| 32 | | | | | | (1) | | | | | |
| 33 | | | | | | | | | | | |
| 34 | | | | | | | | | | x | |
| 35 | | x | | | | | | | | | |
| 36 | | | | | | | | | | x | |
| 37 | | | | | | | | | | x | |
| 38 | | | | | | | | | | | |
| 39 | | | | | | | | | | x | |
| 40 | | | | | | | | | | | |
| 41 | | | | | | (spot) | | | | x | |
| 42 | | | | | | | | | | | |

(1) continuous footings

APPENDIX A-16

MECHANICAL FEATURES

## PROJECT DESCRIPTIONS: MECHANICAL FEATURES

NOTE: Numerals in columns indicate the number of various areas included in each project.

| Project Number | Hot Water Heating System | Air Cond. | Sci. | Home Ec. | Primary | Kitch. | Apr* Gym Cafe | Toilets (mult) | Toilets (single) | Misc. | Total Class Rooms | Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | | | | | | | | | | (A) | 5 | 7 |
| 9 | | | | | | | | | | (A) | 5 | 6 |
| 10 | | | | | | | | | | | 5 | 8 |
| 11 | | | | | | | | 2 | | (A) | 4 | 10 |
| 12 | | | | | | | | 2 | | (A) | 5 | 10 |
| 13 | | | | | | | | 2 | | (A) | 4 | 10 |
| 14 | | | | | | | | 2 | Lounge | (B)(L) | 5 | 11 |
| 15 | | | 2 | | | | | 2 | | | 4 | 10 |
| 16 | | | | | 2 | | | 2 | | (G) | 6 | 9 |
| 17 | | | | | | 4(S) | | | | (K) | 6 | 10 |
| 18 | | | | | 1 | | | | | (A) | 6 | 9 |
| 19 | HWS | | 1 | | | | | 2 | | (M) | 5 | 10 |
| 20 | | | | | | | | 4 | | | 6 | 14 |
| 21 | | | | | | | | 4 | | | 6 | 13 |
| 22 | | | 1 | | | 6(S) | C | | | (J)(K) | 4 | 6 |
| 23 | | | | | | 4+ | C | 2 | | | 5 | 14 |
| 24 | | | | | 2 | | | 2 | Off. | (A) | 6 | 18 |
| 25 | | | | | | | | 4 | | (D) | 6 | 15 |
| 26 | | | | | 2 | | | 2 | Teach. | | 8 | 17 |
| 27 | HWS | | 2 | | | | | 4 | | | 8 | 18 |
| 28 | | | | | | | | 4 | | | 8 | 19 |
| 29 | | | | | | 5(S) | C | 2 | (C) | (O,D,K) | 4 | 23 |
| 30 | | | 2 | | | | | | | (N) | 8 | 15 |
| 31 | HWS | Central | | | 2 | 4+ | C | 2 | Off. | | 8 | 23 |
| 32 | | | 1 | | | | | 2 | | | 10 | 20 |
| 33 | | | | | | | | 2 | | (H) | 12 | 23 |
| 34 | HWS | | 1 | 1 | | 5 | | 4 | | | 7 | 27 |

| Project Number | Hot Water Heating System | Air Cond. | Sci. | Home Ec. | Primary | Kitch. | Apr* Gym Cafe | Toilets (mult) | Toilets (single) | Misc. | Total Class Rooms | Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | | | 1 | | | | | 4 | | (F) | 10 | 18 |
| 36 | | Off. | 2 | | | | | 4 | Off. | (O) | 11 | 31 |
| 37 | | | | | 2 | 6+ | C | 2 | | | 12 | 30 |
| 38 | | off. | 1 | | 2 | 9+(P) | C | 2 | Off. | (F) | 10 | 30 |
| 39 | | | 2 | 1 | | | APR | 4 | (I) | | 11 | 31 |
| 40 | | | 1 | | | | G | 2 | | (E) | 10 | 29 |
| 41 | | | 1 | 1 | | 5+ | CG | 2 | | (Q) | 10 | 36 |
| 42 | HWS | | | | | 5+ | C | 4 | Off. | | 30 | 58 |

+ = plus toilet
(A) Lavs in Each Classroom
(B) Wall Heaters
(C) Two Faculty Toilets Adj. to Student Toilets
(D) Lavs in Cabinet Across Back of Each Classroom
(E) Gym Comp. W/Showers, Lobby With Toilets, Conc. Stand, etc.
(F) Art Room
(G) Point of Add'n Cont. Spans Two Toilets; Both Expanded
(H) Mech. Rm.
(I) R.I.O. For Future Office**
(J) Messy Add'n
(K) Kitch. Equip. Relocated
(L) Lav. in One Classroom
(M) Boiler Mod. Required
(N) Home Ec. Area Rem. + Rem. of Home Ec. Area at Another School
(O) Sci. Rm. Equip. Spec.
(P) All Electric
(Q) Detail Specs for Home Ec. Area
(S) Equipment Relocated
* Apr: "All Purpose Room"; similar to a gym but without showers

** "R.I.O." refers to rough in only and means the necessary piping is installed but not the finished fixtures.

APPENDIX A-17

ELECTRICAL FEATURES

## PROJECT DESCRIPTION: ELECTRICAL

NOTE: Numerals in columns indicate the number of various areas included in each project.

| Project Number | Sound Intercom | Clock and Bell * | Kitch. | Stage | Special Classrooms Lang. Bus. Typ. | Sci. | Home Ec. | Misc. ** | Cafe (C) Gym (G) Apr. | Office | Total Class-rooms | Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | | | | | | | | | | | 5 | 7 |
| 9 | | | | | | | | | | | 5 | 6 |
| 10 | | | | | | | | | | | 5 | 8 |
| 11 | | | | | | | | | | | 4 | 10 |
| 12 | x | | | | | | | | | | 5 | 10 |
| 13 | | | | | | | | | | | 4 | 10 |
| 14 | | | | | | | | | | | 5 | 11 |
| 15 | | | | | | 2 | | | | | 4 | 10 |
| 16 | | | | | | | | | | | 6 | 9 |
| 17 | | | 4R | | | | | (A) | | | 6 | 11 |
| 18 | x | | | | | | | | | | 6 | 9 |
| 19 | | | | | | 1 | | HWS | | | 5 | 10 |
| 20 | | | | | | | | | | | 6 | 14 |
| 21 | | | | | | | | | | | 6 | 13 |
| 22 | x | | 6 | S | | 1 | | (C)(A)(K) | C | | 4 | 16 |
| 23 | | N | 4 | | | | | | C | 2 | 5 | 14 |
| 24 | | N | | | | | | | | 4 | 6 | 18 |
| 25 | | | | | | | | | | | 6 | 15 |
| 26 | | | | | | | | | | | 8 | 17 |
| 27 | | | | | | 2 | | HWS | | | 8 | 18 |
| 28 | | | | | 1 | | | | | 1 | 8 | 19 |
| 29 | | | 5 | S | | | | (A) | C | 1 | 4 | 23 |
| 30 | | | | | | 2 | | (H) | | | 8 | 15 |
| 31 | | N | 4 | | | | | HWS; C.A. | C | 1 | 8 | 23 |
| 32 | | | | | 1 | 1 | | (D) | | 3 | 10 | 20 |

| Project Number | Sound Intercom | Clock and Bell | Kitch. | Stage | Special Classrooms Lang. Bus. Typ. | Sci. | Home Ec. | Misc. | Cafe (C) Gym (G) Apr. | Office | Total Class-rooms | Total Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | | | | | | | | | | | 12 | 23 |
| 34 | | N | 5 | S | | 1 | 1 | (F)HWS | | 3 | 7 | 27 |
| 35 | | | | | 2 | 1 | | (B)(I) | | | 10 | 18 |
| 36 | | N | | | 2 | 2 | | (D)(E) | | 5(G) | 11 | 31 |
| 37 | | N | 6 | S | | | | | C | 4 | 12 | 30 |
| 38 | | | 9(J) | | | 1 | | (B) | C | 1(G) | 10 | 30 |
| 39 | | N | | | | 2 | 1 | | APR | | 11 | 31 |
| 40 | | | | | | 1 | | | G | | 10 | 29 |
| 41 | | N | 5 | S | | 1 | 1 | | C and G | 2 | 10 | 36 |
| 42 | | | 5 | | | | | HWS | C | 3 | 30 | 58 |

(A) Kitchen Equipment Relocated
(B) Art Room
(C) Messy Add'n
(D) Library
(E) Music
(F) Dbl Circuits, Fluor thru-out with one
Incand in Each Area
(G) A/C Area
(H) Home Ec. Area Rem. + Rem. of
Home Ec. Area at Another School
(I) New Transformer Requ'd
(J) All electric

*New Facilities Only
**HWS indicates Hot Water Heating System
CA indicates Central Air Conditioning

APPENDIX A-18

STRUCTURAL MAN-HOUR REQUIREMENTS

NOTE: This summary is identical in format to Appendix A-15. The X's denoting the occurrence of a deviation from the standard structure, described in Appendix A-15, have been replaced by a man-hour allowance. These allowances, totaled in column (d) are intended to eliminate or reduce the deviation (c) between the lowered line of best fit and actual performance. Ideally, the allowances indicated in column (d) would equal the actual man-hour deviations noted in column (c). Columns (a) and (b) indicate the error or difference between columns (c) and (d).

| Project Number | Man-Hours: Error (a) Under | Man-Hours: Error (b) Over | Man-Hours: (c) Dev. from Base Line | Man-Hours: (d) Total Allowances | Man-Hour Allowances: Structural Steel System | Concrete Joists | Concrete Columns and Joists, Non-Load Bearing Walls on First Floor | Borrow Lights | Laminated Beams | Piers or Spot Footings | Two Story | Addition: Ave | Addition: Complex | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 4 | | 19 | 15 | | | | 5 | | 10 | | | | |
| 9 | | 2 | 13 | 15 | | | | 5 | | 10 | | | | |
| 10 | 26 | | 46 | 20 | | | | | 10 | 10 | | | | |
| 11 | 14 | | 24 | 10 | | | | | | 10 | | | | |
| 12 | | 21 | 4 | 25 | | | | 5 | | 10 | | | 10 | |
| 13 | | 2 | 13 | 15 | | | | 5 | | C.F. | | | 10 | |
| 14 | 26 | | 36 | 10 | | | | | | 10 | | | | |
| 15 | 3 | | 48 | 45 | | | 35 | | | 10 | x | | | |
| 16 | | 1 | 31 | 30 | | | | | 10 | 10 | | | 10 | |
| 17 | 12 | | 42 | 30 | | | | | | 10 | | | 20 | |
| 18 | 31 | | 41 | 10 | | | | | | 10 | | | | (B) (B) |
| 19 | 36 | | 46 | 10 | | | | | | 10 | | | | |
| 20 | 11 | | 56 | 45 | | | 35 | | | 10 | x | | | (A) (A) |
| 21 | 14 | | 59 | 45 | | | 35 | | | 10 | x | | | |
| 22 | 5 | | 35 | 30 | | | | | | 10 | | | 20 | |
| 23 | 52 | | 62 | 10 | | | | | | 10 | | | | |
| 24 | | 8 | 7 | 15 | | | | 5 | | 10 | | | | |
| 25 | Outside Consultant | | | | | | | | | | | | | |
| 26 | 69 | | 89 | 20 | | | | | 10 | 10 | x | | | |
| 27 | 54 | | 89 | 35 | | 25 | | | | 10 | x | | | |
| 28 | 18 | | 68 | 45 | | | 35 | | | 10 | x | | 0 | |
| 29 | | 30 | 25 | 55 | 20 | | | 5 | | 10 | | | 20 | |
| 30 | 28 | | 63 | 35 | | 25 | | | | 10 | | | | |
| 31 | 62 | | 128 | 66 | | | | | | 10 | | | 56(C) | 56(C) |
| 32 | | 34 | -34 | | Continuous Footings: | | Arch Dept. did struc. plans | | | 0 | | | | |
| 33 | 8 | | 28 | 20 | | | | | | 10 | | | 10(D) | 10(D) |
| 34 | 42 | | 52 | 10 | | | | | | 10 | | | | |
| 35 | Outside Consultant | | | | | | | | | | | | | |
| 36 | 22 | | 32 | 10 | | | | | | 10 | | | | |
| 37 | | 27 | -17 | 10 | | | | | | 10 | | | | |
| 38 | 73 | | 103 | 30 | | | | | | 10 | | | 20(E) | 20(E) |
| 39 | Outside Consultant | | | | | | | | | 10 | | | | |
| 40 | 47 | | 57 | 10 | | | | | | 10 | | | | |
| 41 | | 16 | 4 | 20 | | | | | | C.F. | | | 20(F) | 20(F) |
| 42 | 5 | | 35 | 30 | | | | | | 10 | | | 20(G) | 20(G) |

(A) Two story add'n to one story school.
(B) Separate food stor. add'n.
(C) Basement (40) + unusual window treatment (16).
(D) Two roof levels.
(E) Steel framing in masonry walls.
(F) Rigid frame system in gymnasium.
(G) Window wall.

APPENDIX A-19

MECHANICAL MAN-HOUR REQUIREMENTS

NOTE: This summary is identical in format to Appendix A-16 which summarizes the mechanical features that distinguish each project. The notations in Appendix A-16 have been replaced by a man-hour allowance intended to eliminate or reduce the deviation (c) between the lowered lines of best fit and actual performance. Ideally, the allowances indicated in column (d) would equal the deviations in column (c). Columns (a) and (b) indicated the error or difference between columns (c) and (d).

| | Man-Hours | | | | Man-Hour Allowances | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Error (a) | (b) | (c) | (d) | | | | | | | | | | | | |
| Project Number | Under | Over | Dev. from Base Line | Total Allow-ances | Heating | Cond. | Sci. | Home Ec | Primary | Kitch. | Gym | Toilets (mult) | Toilets (single) | Lavs. (Clsrm) | Re-model | Misc. |
| 8 | 22 | | 24 | 2 | | | | | | | | | | 2 | | |
| 9 | 15 | | 17 | 2 | | | | | | | | | | 2 | | |
| 10 | 16 | | 16 | | | | | | | | | | | | | |
| 11 | 5 | | 8 | 3 | | | | | | | | 2 | | 1 | | |
| 12 | 7 | | 11 | 4 | | | | | | | | 2 | | 2 | | |
| 13 | 19 | | 22 | 3 | | | | | | | | 2 | | 1 | | |
| 14 | 8 | | 13 | 5 | | | | | | | | 2 | 2 | 1 | | |
| 15 | 13 | | 19 | 6 | | | 4 | | | | | 2 | | | | |
| 16 | 29 | | 49 | 20 | | | | | 2 | | | 2 | | | | 16(A) |
| 17 | 18 | | 28 | 10 | | | | | | 10 | | | | | | |
| 18 | 6 | | 9 | 3 | | | | | 2 | | | | | 1 | | |
| 19 | 3 | | 37 | 34 | 30 | | 2 | | | | | 2 | | | | |
| 20 | 19 | | 23 | 4 | | | | | | | | 4 | | | | |
| 21 | 16 | | 20 | 4 | | | | | | | | 4 | | | | |
| 22 | 42 | | 57 | 12 | | | 2 | | | 10 | | | | | | |
| 23 | 71 | | 75 | 4 | | | | | | 2 | | 2 | | | | |
| 24 | 26 | | 34 | 8 | | | | | 2 | | | 2 | 2 | 2 | | |
| 25 | 27 | | 32 | 5 | | | | | | | | 4 | | 1 | | |
| 26 | 44 | | 50 | 6 | | | | | 2 | | | 2 | 2 | | | |
| 27 | | | * | 38 | 30 | | 4 | | | | | 4 | | | | |
| 28 | 25 | | 29 | 4 | | | | | | | | 4 | | | | |
| 29 | 23 | | 38 | 15 | | | | | | 10 | | 2 | 2 | 1 | | |
| 30 | 5 | | 25 | 20 | | | 4 | | | | | | | | 16(C) | |
| 31 | 22 | | 100 | 78 | 30 | 40 | | | 2 | 2 | | 2 | 2 | | | |
| 32 | | 6 | -2 | 4 | | | 2 | | | | | 2 | | | | |
| 33 | | 16 | -14 | 2 | | | | | | | | 2 | | | | |
| 34 | 15 | | 55 | 40 | 30 | | 2 | 2 | | 2 | | 4 | | | | |
| 35 | 30 | | 37 | 7 | | | 2 | | | | | 4 | | 1 | | |
| 36 | 23 | | 41 | 19 | | 8 | 4 | | | | | 4 | 2 | | | |
| 37 | 3 | | 9 | 6 | | | | | 2 | 2 | | 2 | | | | |
| 38 | 42 | | 61 | 19 | | 8 | 2 | | 2 | 2 | | 2 | 2 | 1 | | |
| 39 | 0 | | 12 | 12 | | | 4 | 2 | | | | 4 | 2 | | | |
| 40 | 36 | | 42 | 6 | | | 2 | | | | 2 | 2 | | | | |
| 41 | | 4 | 6 | 10 | | | 2 | 2 | | 2 | 2 | 2 | | | | |
| 42 | 4 | | 42 | 38 | 30 | | | | | 2 | | 4 | 2 | | | |

(A) Hot water heating system.
(C) Remodel Home Ec. area in two separate schools.
(D) Hot water system + central air conditioning.
(E) Relocate existing kitchen equipment.
(F) Db'l circuits: fluor and incand. lighting in all areas
(G) New transformer.
(I) Spot air conditioning.

APPENDIX A-20

ELECTRICAL MAN-HOUR REQUIREMENTS

NOTE: This summary is identical in format to Appendix A-17 which summarizes the electrical features that distinguish each project. The notations in Appendix A-17 have been replaced by a man-hour allowance intended to eliminate or reduce the deviation (c) between the lowered lines of best fit and actual performance. Ideally, the allowances indicated in column (d) would equal the deviations in column (c). Columns (a) and (b) indicated the error or difference between columns (c) and (d).

| Project Number | Man-Hours: Error (a) Under | Man-Hours: Error (b) Over | Man-Hours: (c) Dev. from Base Line | Man-Hours: (d) Total Allowances | Man-Hour Allowances: Sound Intercom | Clock and Bell | Kitch. | Stage | Special Classrooms: Bus. Typ. Lang. | Special Classrooms: Sci. | Special Classrooms: Home Ec. | Special Classrooms: Gym Apr. | Office | Mech. | Lib Music Art | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 26 | | 26 | | | | | | | | | | | | | |
| 9 | 11 | | 11 | | | | | | | | | | | | | |
| 10 | 44 | | 44 | | | | | | | | | | | | | |
| 11 | 16 | | 16 | | | | | | | | | | | | | |
| 12 | 7 | | 23 | 16 | 16 | | | | | | | | | | | |
| 13 | 16 | | 16 | | | | | | | | | | | | | |
| 14 | 36 | | 36 | | | | | | | | | | | | | |
| 15 | 22 | | 26 | 4 | | | | | | 4 | | | | | | |
| 16 | 36 | | 36 | | | | | | | | | | | | | |
| 17 | 15 | | 25 | 10 | | | 10(E) | | | | | | | | | |
| 18 | 17 | | 33 | 16 | 16 | | | | | | | | | | | |
| 19 | 39 | | 57 | 18 | | | | | | 2 | | | | 16(A) | | |
| 20 | 33 | | 33 | | | | | | | | | | | | | |
| 21 | 20 | | 20 | | | | | | | | | | | | | |
| 22 | 5 | | 47 | 42 | 16 | | 10(E) | 8 | | 2 | | | | | | |
| 23 | 49 | | 57 | 8 | | 4 | 2 | | | | | | 2 | | | |
| 24 | 23 | | 29 | 6 | | 4 | | | | | | | 2 | | | |
| 25 | 19 | | 19 | | | | | | | | | | | | | |
| 26 | 48 | | 68 | | | | | | | | | | | | | |
| 27 | 48 | | 10 | 20 | | | | | | 4 | | | | 16(A) | | |
| 28 | 4 | | 34 | 6 | | | | | 4 | | | | 2 | | | |
| 29 | 14 | | 31 | 20 | | | 10(E) | 8 | | | | | 2 | | | |
| 30 | 7 | | 56 | 20 | | | | | | 4 | | | | | | 16(C) |
| 31 | 8 | 1 | 15 | 48 | | 4 | 2 | | | | | | 2 | 40(D) | | |
| 32 | 7 | | 7 | 16 | | | | | 4 | 2 | | | 2 | | 8 | |
| 33 | | 9 | 33 | 42 | | | | | | | | | | | | |
| 34 | 30 | | 56 | 26 | | 4 | 2 | 8 | | 2 | 4 | | 2 | 16(A) | | 4(F) |
| 35 | 8 | | 38 | 30 | | | | | 8 | 2 | | | | | 8 | 8(G) |
| 36 | 4 | | 20 | 16 | | 4 | | | 4 | 4 | | | 2 | 8(I) | 8 | |
| 37 | 13 | | 37 | 24 | | 4 | 2 | 8 | | | | | 2 | | | |
| 38 | 5 | | 21 | 16 | | | 4 | | | 2 | | | 2 | 8(I) | 8 | |
| 39 | 11 | | 33 | 22 | | 4 | | | | 4 | 4 | 4 | | | | |
| 40 | | 22 | 4 | 26 | | | | | | 2 | | 4 | | | 16 | |
| 41 | | 11 | 9 | 20 | | 4 | 2 | 8 | | 2 | 4 | 4 | 2 | | | |
| 42 | | | | | | | 2 | | | | | | 2 | 16(A) | | |

* Outside consultant.
(A) Addition spans existing toilet area.
(B) Extensive remodeling of another school.
(C) Remodel of home economics area in two separate schools

VITA

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