COMPUTERIZED SCHEDULING OF MANPOWER AND MATERIALS FOR MAINTENANCE, MODIFICATION, AND CONSTRUCTION

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of Study: COMPUTERIZED SCHEDULING OF MANPOWER AND MATERIAL FOR MAINTENANCE, MODIFICATION, AND CONSTRUCTION

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se of Study: The purpose of this study was to determine, from a thorough literature search and a formal evaluation of alternative approaches, the practicality of computerizing the scheduling function for a specific organization within the Research and Development Department of Phillips Petrole Company. If such a program is feasible, to propose a workable system to accomplish the task.

ngs and Conclusions: Computerized scheduling of manpower is being done t varying degrees in different industries. The most common applications involve large projects and some version of project planning by computer. There were no indications of interfacing the material availability with manpower scheduling, or of craft sequencing.

The system proposed to handle the task includes sequencing of separate crafts on the same job, assuring material availability before scheduling and generation of management information reports on demand as well as the routine scheduling of the daily work schedule of four crafts involving 50 craftsmen.

SER'S APPROVAL: ______________________

ACKNOWLEDGMENTS

This study was undertaken in an effort to improve the effectiveness of the scheduling function in a specific organization within Phillips Petroleum Company. The understanding and consideration of Phillips Research management was necessary and is greatly appreciated.

A special word of thanks to Dr. Ralph Catalanello, Assistant Professor of Management, who served as advisor for this report. His advice and council contributed significantly to the composition of the report.

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CHAPTER I

Introduction

One of the major problems confronting managers of maintenance, ıodification, or construction craft people today is how to increase the roductivity of these organizations. With a shortage of skilled and ompetent craftsmen and the increase in labor costs, there is constant ressure to increase work output with fewer employees. As this manpower queeze progresses, it soon becomes critically important that the scheduling function be as near optimum as practical. If for any reason there is mix up by the scheduling system the cost of idle manpower begins to ıount very rapidly. In many cases the scheduling of men and materials o a new job is the function of one man who, under normal conditions, perates a reasonably well organized and functioning system. Being human e is subject to the same errors, mental lapses, or tempermental variations hat plague us all. He goes on vacation, gets sick, and attends weddings nd funerals. During all these time periods the scheduling and planning unction must go on. When he is not on the job his replacement is normally omeone who has a job of a completely different nature and will operate at different rate or handle the same problems differently. All of these proble ead to inconsistency in the scheduling function. If this function could be, or the most part, reduced to a series of logical decisions it should be easible to improve the overall efficiency by having a computer make these utine decisions. The importance of computerizing this function is evident y the partial list of references at the end of this paper.

Typical of many organizations faced with this problem today is the aintenance and Modification Branch of the Administrative Division of e Research and Development Department of Phillips Petroleum Company. ne Branch provides services of a semi-technical and technical nature to e Research Center of Phillips in Bartlesville, Oklahoma. (Figure 1 is an ganization chart for the Branch). There are four separate craft organi- tions providing services over a very wide range of skill requirements. ectricians for example range from light bulb changing to 13,200 volt ower system trouble shooting. Refrigeration handles routine heating and oling systems for human comfort and also highly complex scientific stems requiring extreme accuracy at sub-zero temperatures. The echanical section involves the skills of the carpenter, painter, mechanic, sulator, machinist, plumber, truck driver, mover, millright, in fact most nything not covered by the other three higher skill level sections. The strument section handles anything from routine instrument repair to mputer system troubleshooting.

In this organization, the scheduling function is now accomplished with manual system revolving about one individual in a very critical position. e prepares a daily work schedule for each craft foreman, indicating the timated man-hours of work his crew is assigned. The scheduler must ke into account the availability of parts and equipment needed for the b and must not schedule the job until all needed equipment is available.

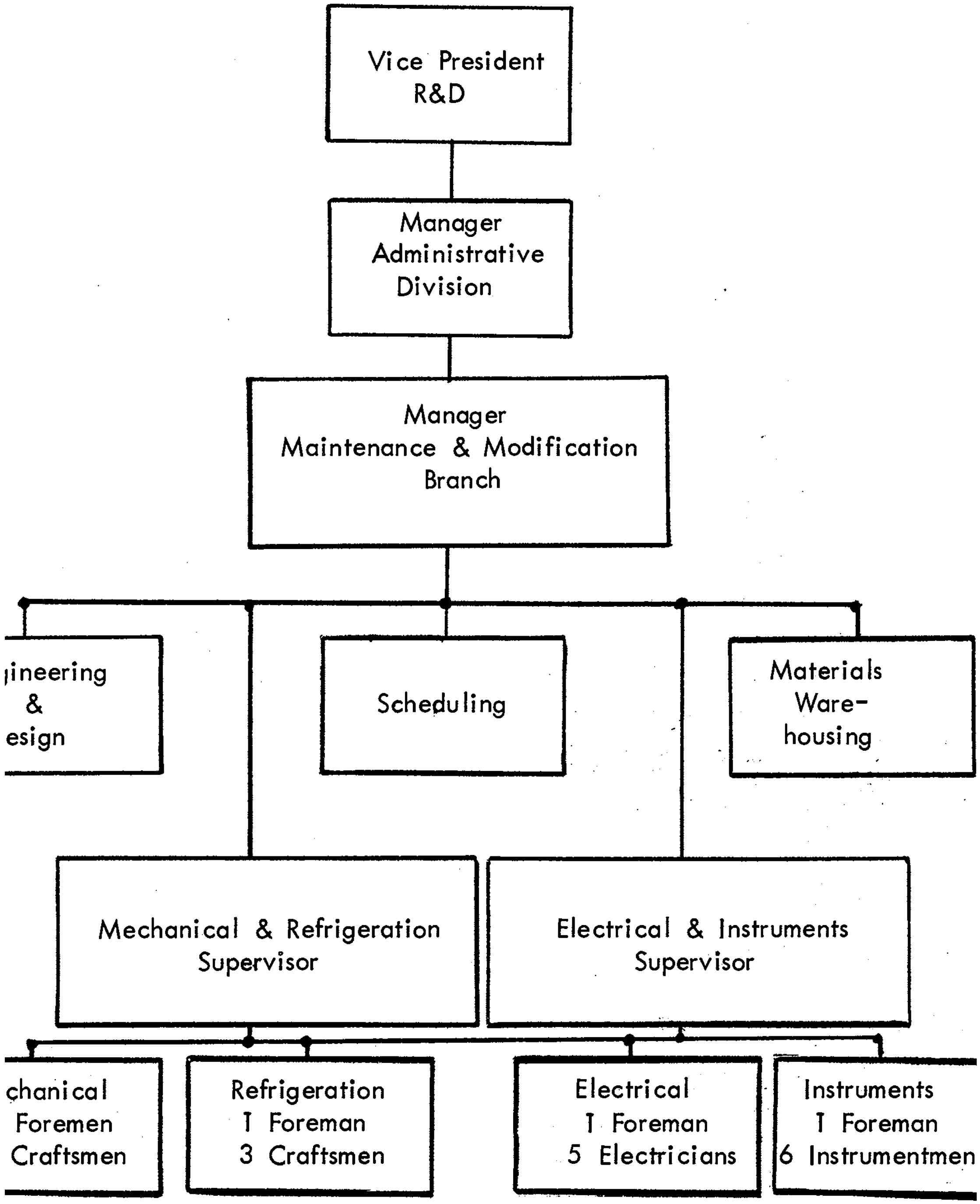
le must be a master at balancing the demands of operations against the vailable manpower in the craft required. A large number of his jobs nvolve two or more crafts and often they cannot work simultaneously nd must be sequenced onto the job at proper time intervals. In this osition he is naturally the funneling point for all craft work and as uch is the primary contact for R&D personnel desiring work to be done r seeking information about a specific job. This interface between hose requiring a specific service and those craftsmen performing the ervice is critical and should receive more attention that the scheduling unction of his job will allow.

Purpose of Study

The scheduling function, being as critical as it is to the optimal use f available manpower, is in need of some in-depth study to determine a ethod of improving on the performance of the human operator of the unction. The purpose of this study is to determine the practicality of omputerizing the more routine parts of the job. The benefits of this hange would be at least two-fold. If a program can be designed that ill always make the same decision, given the same information concerning material availability, manpower requirements, and job requirements, daily schedule can be prepared with increased consistency and effectiveess. At the same time the scheduler will have more time to apply to unctions that cannot readily be adopted to a computer program. The net esult should be improved efficiency of the organization in question.

If such a system is practical this study will outline a model that ill accomplish the desired result. The proposed system will have to be erated by the same personnel that operate the present system. By cessity the system cannot require more time, and hopefully would be s time consuming, than the present system. The study will include ing of the man-machine interface and a comparison of this elapsed e to the time now required for the equivalent actions to take place.

A secondary purpose, assuming successful completion of the mary purpose, will be to adopt the same model for management ormation report generation. Several reports are currently being nerated by an alternate system that could be abolished completely this proposed system could be adopted for that purpose.



MAINTENANCE & MODIFICATION BRANCH

FIGURE 1

Scope of the Study

The first step in the study was to determine from a search of rrent literature if this type of program has been used successfully in ıilar industries, and, if not, can the work that has been done be ised to fit the needs of this program. Can a computer program be veloped that will (1) prepare a daily schedule for each craft, taking o consideration all the restraints now considered by the scheduler, keep a running account of material availability and status of ordered terial, alarming past due deliveries, and (3) generate required management information reports.

The second step involves the development of portions of the model o a form usable by computer programmers for program generation. This del should consider the operating constraints of the present scheduler d makes use of his years of practical experience in establishing its cision trees and data tables.

The third step involves a simulation of the proposed system using a ıched tape to present the scheduler with the format he will encounter m the computer and timing his data entry time. These times are then npared to measured time for performing the equivalent task now.

A listing of the operating constraints of the system is presented in ble I.

TABLE I

System Constraints

Be operable from remote locations using leased lines for communication through a teletypewriter or equivalent to a central facility.

The operator should be able to proof data off line.

Be capable of accepting file updates during normal working hours.

Schedule all available manpower for eight hours per work day.

Properly sequence crafts onto jobs requiring more than one craft in sequence.

Be capable of keeping records on purchases, date ordered, expected delivery date, date received, and cost of materials.

On request issue status report of ordered materials.

Flag jobs whose material delivery is going to delay start of work beyond the date required for the schedule to stay current.

Organization of Paper:

Chapter two discusses the research that was done and some of the ts that are being made in this particular area. An effort was made to e the common areas and point out the areas where the need for further lopment or change exist. Chapter three details the present scheduling m in use at the Phillips Research Center in Bartlesville. The areas of ness are pointed out with suggested improvements that any revised system ld incorporate. Chapter four is a discussion of the proposed system and p-by-step discussion of a typical work order as the system will handle Chapter five is a comparison of the effectiveness of the two systems and monstration of the advantages of the proposed system over the present em. Chapter six is a summary with the implications and conclusions le that relate to the recommendations for a change in scheduling ems.

ıpter one

Summary:

The problem of optimizing the scheduling function is serious in areas ıling with the scheduling of skilled craftsmen who must interface with er craft and satisfy operating personnel and their requirements. This study poses to determine the practicality of computerizing this function and, if sible, to develop enough of the model to demonstrate its feasibility. s model will then be compared to the present operating system in some tical areas.

CHAPTER II

Review of Related Literature

Much has been written on various scheduling systems both manual d automatic. This review will cover some of the more typical pers beginning with those having general interest and following through those most nearly paralleling the aims of this paper.

The literature available on computerized scheduling runs the full ctrum of human attitudes from the most optimistic to very pessimistic. also covers applications from the simplest heuristic model to the most nplex dynamic models. A careful study of papers exemplifying the namic linear programs[1,2,3] led to the conclusion that, in retrospect, ms obvious. The complexities of this type programming, (e.g. Strict thematical formulation of all constraints, defining the multi-dimensional

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[1]R. P. Jewett, "Minimum Risk Manpower Scheduling Technique" nagement Science, XIII (June, 1967), pp B578-B592.

[2]S. A. Lippman and others, "Algorithms for Optimal Production neduling and Employment Smoothing", Operations Research, XV ovember, 1967), pp 1011-29.

[3]S. A. Lippman and others, "Optimum Production Scheduling and ployment Smoothing with Deterministic Demands", Management Science, / (November, 1967), pp 127-58.

variables, and development of specific algorithms for the non-linear ·ions involved), are not required for the relatively simple problem at . The time required to develop a dynamic model to accomplish our ed objectives would be far greater for this type program than the /alent heuristic model. The key seems to be in the relative size of ›rogram and the number of variables involved. The job at hand is enough to fully comprehend without having the organization necessary he more involved model.

As the field narrows, to those papers more closely associated with ;cheduling of maintenance and modification craftsmen, the understanding s. One paper of a more pessimistic nature discusses the various hazards untered by a generation or so in the fields of discreet programming and ·inatorial mathematics. Typical of these hazards is the problem of the l increase in the number of variables to be considered with only t increases in the number of state variables. Selection of the proper ematical method to handle large-scale problems is another hazard that :tly affects cost. The running time of the program is not a direct ›rtion to the problem size. The solution method can affect run time ; much as a factor of 20 to 1 between two alternatives. Spitzer ts using heuristic methods to solve 1000 variable problems as early as . Regardless of the approach used to solve the problem he feels there d be sufficient economic incentive to demand the action be taken. lso points out that a secondary benefit of computerized scheduling is ımount of management information already available in such a system.

could easily be manipulated into a form usable by management.[4]

On the opposite end of the human attitudes spectrum is a paper J. E. Sanford covering the miracles performed by a vendor of comterized scheduling for small manufacturing businesses in the northeastern S. This vendor supplies his customer with a teletype which links to IBM 1130 and through it to the giant data processing computers at iversity Computing Corporation in Dallas. The customers of this company growing faster than the competition and believe that their growth is ributable to the multiple benefits (e.g., minimum cost, maximum production, immediate picture of the schedule that will yield these attributes so that eman and production line worker know exactly what to do next) to be ived from computerized scheduling.[5]

More nearly in the center of this human attitudes spectrum are a up of papers by industrial types who are directly involved in making a eduling system function. One of these papers deals with the scheduling projects and an Esso Research and Engineering evaluation of five nmonly used computer programs, PERT (Program Evaluation and Review hnique), CPM (Critical Path Method), RAMPS (Resources Allocation and ltiple Project Scheduling), Richfield's Critical Path and Manscheduling tem, and Continental Oil's Project Planning System.[6] Table II compares

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[4]M. Spitzer, "Computer Art of Scheduling Making", Datamation, XV ril, 1969), pp 84-86

[5]J. E. Sanford, "Computer Eases Job Scheduling", Iron Age, CCVII bruary 18, 1971), pp 46-48

[6]J. T. Kurzeja, "When Work Schedules Need Computers", Hydrocarbon cess and Petroleum Refiner, XLIV (April, 1965), pp 171-174

se five systems on six separate items of importance from a cost stand-nt.

TABLE II

Comparison of Computer Scheduling Systems

	PERT	CPM	RAMPS	Richfield	Conoco
nsiders Time	Yes	Yes	Yes	Yes	Yes
nsiders Manpower	No	No	Yes	Yes	Yes
nsiders Expediting Cost	No	Yes	Yes	No	No
ınpower Smoothing	None	None	Excellent	Good	Excellen
ta Preparation Time	Low	Low	High	Low	Low
U Time	Low	Low	High	Low	Mediur

ile all of these systems have their individual strong and weak points, the ›up has a significant problem when being considered for the level of job are considering. Their sophistication exceeds that required by such a ıt margin as to deem them impractical from a cost standpoint.

Two papers of very practical value deal with the same problem we are ing to solve. American Oil's Texas City, Texas, Maintenance Division has daily schedule, computer prepared, which they put in the hands of the ıftsmen involved the day before the work is to be done. This system does thing but prepare the schedule from work orders having cleared the planning ›erintendent's desk. One thing of significance, for our use, that is omitted m this paper is the type of computer used. The impression is given that ›y may be using an inhouse scientific machine as opposed to a business ented machine.[7]

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[7]"Maintenance Crews See What's Next", Oil and Gas Journal, IX (November 8, 1971), p. 74

The second paper is concerned with the evolution of a maintenance heduling system installed by Atlas Chemical Industries, Inc. This computer/ ›mmunications system maintains complete local plant control over work ders and stock items and has resulted in significant improvement in the ›mpany's maintenance operations. The Atlas system serves four plants, heduling 1100 work orders per plant at any given time. The steps taken ' these engineers and plant managers are significant in that they closely ırallel the steps taken by Phillips Research Department Maintenance ›rsonnel to date. They had a system of sorts, manually controlled, that emed to get the job done for several years. A high-level maintenance ıprovement committee studied the system, with a formalized manual ıintenance system in each plant resulting from their study. After several ›ars of using this formal system it became apparent that these manual stems were no longer adequate. The volume and complexity of maintenance ›rk became so great that the effectiveness of the priorities that had been t up was being lost. One plant manager contracted with a local service reau to set up a system based on automatic data processing. Feeling ɔt individual systems for each plant would be prohibitive, costwise, mpany management optioned for a central system using teleprocessing uipment to link each plant to the Central Computer. This system prepares ɘ schedule for each plant and keeps track of 40,000 spare parts and ıintenance items from a stocking point of view. It has the ability to swer specific inquiries and generates weekly status reports on incomplete ›s and craft backlog. Atlas uses a 65K core machine with six magnetic ɔe units, three disk units, a card punch and reader in each plant and in e central facility, and a 1100 line per minute printer. The same system ;o does a variety of accounting work, is expandable in unit steps, and is ing evaluated for other similar uses throughout Atlas Chemical.[8]

In summary, there are many ways to approach the problem of man- wer and material scheduling. The literature on the subject has much to y about a lot of things. From our study of this literature we can select /eral ideas and concepts that fit into our particular set of requirements ən build and expand from these. From the successful operations reported, ɘ common factors that are also common to our situation are interesting. The use of a central computer, already in use for other purposes, is a y factor in the economics of the problem. (2) The people using the system ɘ not required to fully understand the internal workings of the system. ey have a local machine of some type through which the computer and the lividual communicate. (3) The ability to generate management information ɔorts is an added plus that in our case has major significance because of ɘ current computer cost for these same reports.

The review indicates a broad span of complexity for scheduling programs d hints at an equally broad cost range. We can be comforted in knowing ıt the computerized scheduling of material and manpower already is being ɔlied in the petroleum industry in much the same form as required by our ·ticular organization.

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[8]C. R. Chamberlin and D. R. Freese, "Maintenance Scheduling Goes the Computer", Management Research, LVIII, (August, 1969), pp. 2-7.

CHAPTER III

The Existing System

Engineers and Scientists throughout Phillips R&D can initiate a ıest for maintenance, modification, or construction work by filling a Maintenance and Modification work order (Phillips form 7429, '1). Table III specifies the information required on this form from originator. Figure II is a sample of the form.

TABLE III

Maintenance and Modification Work Order
Originator's Required Information

1. Name
2. Location (of Originator)
3. Phone Number
4. Date Work Order Prepared
5. Date Work is Available
6. Identification and Location of Equipment or Work Site
7. Priority Code (See Table IV)
8. Branch Code
9. Charge Number
10. Required Completion Date
11. Description of Work to be Done
12. Approval Signature
13. Authorized Code - (Initials of Approved Signature)

Having filled in this information, the engineer forwards the form to ɔffice of the Scheduler. In routine cases he uses company mail or a ily pickup by maintenance truck drivers. If he has an emergency requiring mediate service he may phone the work order to the maintenance and odification radio room. The radio operator then locates the required fore- an and transmits only the information necessary for him to act on the job. e radio operator then completes the work order request and gives it to e scheduler for entry into the management information system. On all bs the scheduler gives the work order a coded number indicating the month d the sequence of the work order i.e. (11-981 indicates the 981st work der of November). This number is used by the computer to identify the b for reporting purposes. The original copy is sent by company mail to e Computing Department for keypunching and entry into the computer. e work order is then assigned to a "prime" foreman who estimates the job · his craft and indicates the sequence of any other craft that may be eded. If other crafts are required, the "prime" foreman writes a work der for the sequential crafts using the same work order number originally signed by the scheduler for the job. Each foreman involved on the job mpletes the necessary parts of the form (see Table V) before returning e work order to the scheduler for further processing.

IGINATOR ________ LOCATION ________ TELE. NO. ________ DATE PREPARED ________ DATE AVAILABLE ________

UIPMENT AND UIPMENT LOCATION ________ APPROVED BY (NAME & TITLE) ________ AUTHORIZED CODE 22 23 24 25

WORK ORDER - DESCRIPTION OF WORK TO BE DONE (COLS. 26-49)

MATERIAL, SUPPLIES & TOOLS REQUISITION

QUANT.	DESCRIPTION	COND.	STOCK NO.	UNIT OF MEASURE	CENTS OMITTED AMOUNT

Q.	CRAFT	MEN X HOURS	M - H

ESTIMATED JOB COST	COLS. 50-69
1. Craft Cost	
2. Materials	
3. Other	
4. Total Cost	

FOREMAN'S TIME TO ESTIMATE JOB

MINUTES 70 71 72 73

TOTAL MATERIAL COSTS

DELIVER TO ________

ATTENTION ________

OB DESCRIPTION (CHECK ONE) (74)

☐ 1. Emergency ☐ 2. Modification & Construction

☐ 3. Maintenance ☐ 4. Preventive Maintenance

ORM 7429 11-71

ESTIMATED CLASS HOURS

SPECIALIST 75 76 77 78	SENIOR 79 80 81 82	MECHANIC 83 84 85 86	B-MECHANIC 87 88 89 90	UTILITY-MEN 91 92 93 94

JOB FOREMAN ________ DATE COMPLETE ________

APPROVAL OF ORIGINATOR ________ DATE SIGNED ________ FOREMAN'S CODE 97 98

SAMPLE MAINTENANCE AND MODIFICATION WORK ORDER

TABLE IV

Priority Codes

- Emergency - Takes precedence over all other work - automatically justifies overtime if required.

- This is an urgent order - Work must start within two working days from receipt of work order - High loss potential.

- This is essential work - planning and estimating should be completed within three work days. Work should start within 8 days of receipt of work order. Further delay involves high loss potential.

- Routine M&M work. Timing is not of immediate importance. Work should start within 30 days of receipt of work order.

TABLE V

Maintenance and Modification Work Order Information Required from Craft Foreman Before Job Starts

1. Estimated Class Hours (Senior, Mechanic, Utility, etc.)
2. Sequence Number - if Sequencing is required
3. Craft Code
4. Total Man Hours Estimated
5. Total Labor Cost Estimated
6. Total Material Cost Estimated
7. Other Cost - Outside Contractor - Welder, etc.
8. Total Estimated Cost
9. Materials List
10. Where Materials are to be Delivered
11. To Whose Attention are Materials to be Delivered
12. Time Required to Estimate

The Scheduler checks all information on the work order for accuracy readability. Assured of the correctness of the information on the work er, he then files the second and third copies by the day it should be eduled to be completed on time. He sends the 4th and 5th copies to the rehouse for material procurement. The originator has the 6th copy.

Now the system is stalled waiting on materials. If the material ; not arrived by the time the scheduler gets to the work order in his ᵊ, he should notify the originator that his job will not start in time be completed by his requested completion date. When the material ; been placed in a warehouse "hold" location for the job, the 4th ɔy of the work order is returned to the scheduler to indicate the ꞉sence of all requested materials at the warehouse. The scheduler then st rank that job against all other available jobs for scheduling the avail- 'e manpower. When the job is scheduled the number 3 copy of the rkorder is given to the craft foreman, the number 2 copy is sent to nputing as notification of scheduling, and the number 4 copy is returned the warehouse to indicate the desire for material to be delivered to location required.

The process of ranking the orders for each craft and making out the ly schedule for each craft gets so involved and time consuming that the eduler at times lets the other duties of his job, primarily coordinating l consulting, slip. These functions are very much needed and at times sorely missed.

Each day the foreman involved with a work order reports the status his jobs to the scheduler who then uses that information to help determine next day's schedule. The foremen also give the scheduler a daily record hours worked on each job by craft class. This record is used to account actual man-hours worked on a job and determines the actual labor cost rged to a feature number for that work order number.

When a job has been completed the foreman signs the number 3 py, dates it as completed, gets the originator's approval to end the b, and returns the copy to the scheduler. The scheduler sends this copy the computer to close out the job as far as the monthly reports are ncerned. The number 4 copy, returned to the foreman with the material livery, is filed for six months. This seems to be a hold over from times ıen all reports were generated from hand counting of old work orders. ere is still an occasional need for some reference to this file but generally e need is not critical. The warehouse files their copy (#5) for six onths to be used primarily as a key to purchase orders written from the aterial list. The three copies sent to computing are destroyed as they are y punched and computing destroys the stored record after the reports using e information are completed. The originator usually throws his copy away on after his job is satisfactorily completed.

CHAPTER IV

Proposed System

Chapter IV presents the objectives of the proposed system then a discussion of the benefits and differences of the proposed system when ›ared to the existing system.

TABLE VI

Objectives of Proposed System

1. To achieve more efficient planning and scheduling of maintenance operations.
2. To gain more effective utilization of manpower.
3. To gather the data needed for better continuing analysis and evaluations of maintenance operations.
4. To achieve more efficient warehouse operations.
5. To develop the capability to absorb additional record-keeping activities without adding manpower or space.
6. To explore the possibility of achieving some savings in existing manpower and computer cost.

For the time being the system will use the work order form presently se. The priority system can also be used in its present form. The ɘnt system of reports will be scrapped with a net savings to the R&D ıet of $6600 per year. In their place will be a condensed summary rt that will fill the needs of R& D management. The IBM 1800, now g used exclusively for technical work, will be the main frame used for

's service. A monthly charge for CPU time and disk rental would be
e only computer charges to Administrative Division. The only additional
nthly charge will be approximately $200/month rental on two teletype
minals. The wiring for these units is available. Total cost for the
tem including paper will be around $4000 per year.

The first deviation from the present system is in the action taken by
e scheduler upon receipt of the work order. After giving the order a
mber, he then establishes the computer file by typing the essential
ormation on the teletypewriter. He does this "off line" one line at a
ne. This allows him to proof and correct his message before sending it
the computer. He can work each order as it is received. He will
ke a second entry into this file when the job is estimated and can then
ise or update the job file any time it becomes necessary. He has
option of forcing any one job to the top of the computer's priority
at any time. His last entry to the file will be to close the job after
is complete. The computer will retain the complete file until the
nthly summary reports are printed.

The next significant area of difference is in the handling of
terial orders. The purchasing agent can at his discretion ask the
nputer for the listing of unordered materials. His printer will list the
v orders in numerical order with a complete listing of required materials.
en he has determined the status of each item he will notify the computer
to its availability. The computer will file the job in its availability
scheduling stack according to its queing rules or in its waiting on

aterial file. The scheduler can, at will, request a printout of the current aiting on material file and receive a listing, by work order number, of ıe materials still on order. As materials are received the stockroom will pdate this file.

The real time savings involved for the scheduler is the next area f difference in the two systems. As late as 4:00 P.M. he can complete is updates of all files and request the next day's schedule. The computer ill give him the schedule for each craft, then upon request from the ockroom, print out the material to be delivered to the job sites the ›llowing morning.

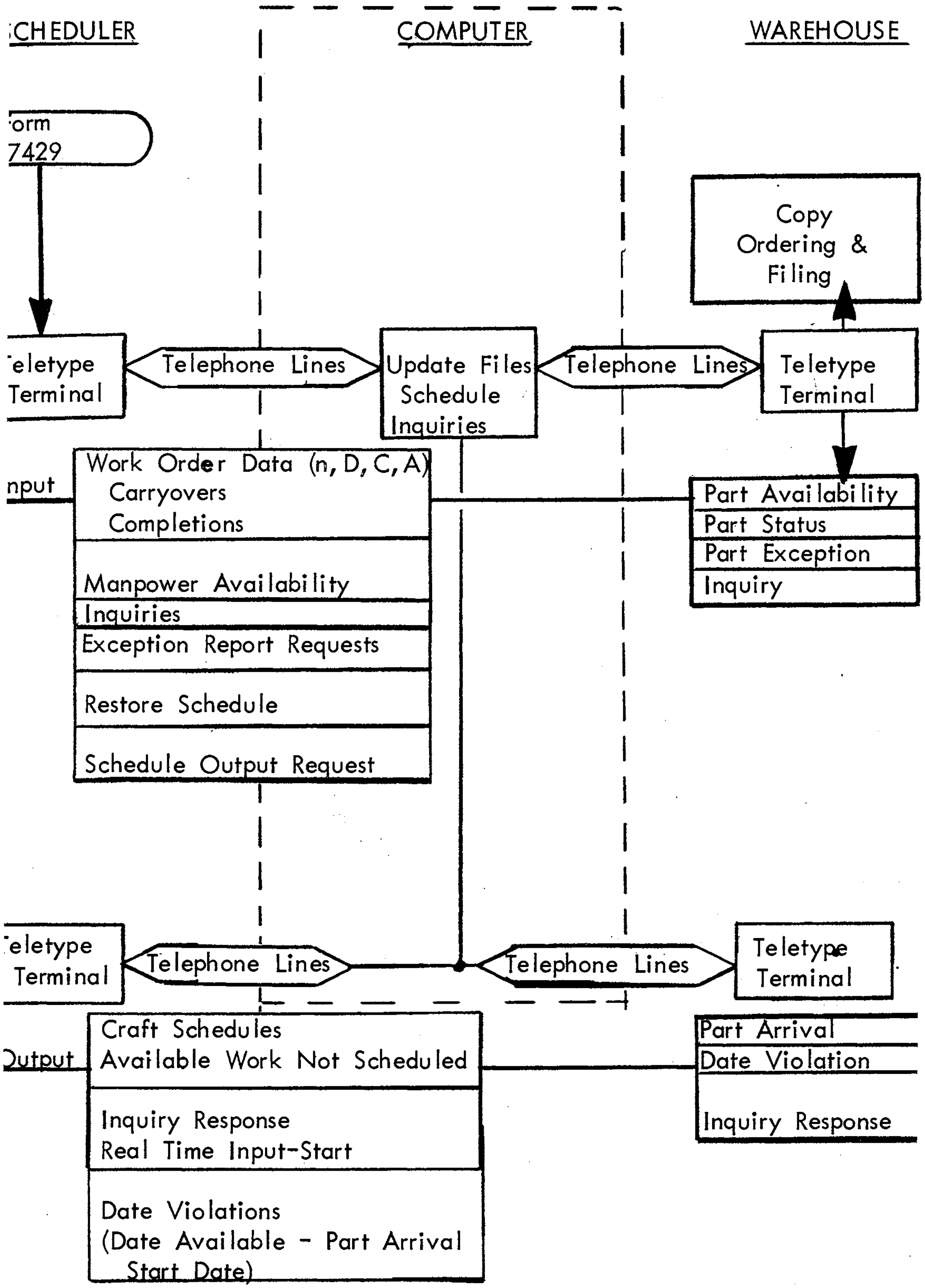
The last area of difference involves the foremen. Up to this point ıe foremen should notice very little difference in their daily operations. nder the present system the foremen are required to turn in their carryovers he hours worked on each job, the jobs that will carry over, etc.), before oon each day so that the scheduler can start preparing his schedule for ıe following day. Under the proposed system the foreman can wait until uch later in the day to indicate these items to the scheduler. This ıould result in more accuracy in the reporting and allow the foreman to ake fullest use of his men. The other item designed to get more efficient se of manpower is the listing of all available jobs on each day's schedule ith no indication of estimated manhours. The computer can adjust aterial deliveries to accommodate more work than would normally be :heduled. For example; if the scheduled eight hours of work is being ompleted each day and additional work is being done, the computer could be requested to increase material deliveries to include enough jobs for ten estimated hours. In any case, the foreman could have the option of asking the stockroom for delivery of any material available in hold. The jobs on his schedule will be listed in the order of priority so that he may use more initiative than is now allowed to make most effective use of his men.

A feature of this system that will aid the scheduler in his coordinating activities is the ability to request a listing of jobs whose start will be delayed because of material delivery. There are two types of indications he will receive. The purchasing agent will estimate, from his experience, the delivery of all purchased materials. This date will be used as an early warning system in case the originator cannot live with the estimated delivery date. The second indication will be from the computer when it should schedule a job and material is not available. This will be a positive no start signal. The scheduler will notify the originator in either case.

The Proposed Model

Figure III is the Input/Output User Interaction Overview. This figure gives a simplified view of the system and its inputs and outputs. Th inputs from the scheduler and warehouse are entered through teletype terminals to the computer where the program performs the required action and immediately returns an output to the inquiring location through the sam instrument used to request service.

MAINTENANCE AND MODIFICATION CRAFT SCHEDULING



Input/Output User Interaction Overview

FIGURE III

A walk through of a typical work order as it is handled by this ›posed system will answer most questions that will arise. The program ll have a data entry section whose function is to edit all incoming data, ether from the scheduler or from the warehouse clerk, for correctness form. Appendix B shows the proper form for all data files. After ;sing the incoming data edit the action code (N, D, C, A) is checked determine the next sequence of events.

An "N" represents a new entry. With each new entry the program lculates the date work should start to meet the customer requirements. ter calculation, this date is compared to the present date and date avail- le for feasibility. If there is no conflict the data will be processed o the proper files where it is retained for further use.

A "D" action code requests the deletion of either a complete work ler or a particular part that had been ordered. In either case, several es must be updated when this action is indicated.

A "C" requests a change in some particular file, parts list, sequence ıft, carryover, or start date.

The "A" code is provided primarily to allow adding additional ıterials to a work order after its original filing. All of these codes, , C, D, N), require action of the program and acknowledgment to the ıder that the request has been serviced.

If this is a new work order the scheduler would type in a data line ıilar to the following:

N-1-070026-LP4208-0708-82F-0796-0706-REPAIR FLOW CONTROLLER.

The computer program will interpret this to be a new work order l), with a (1) priority, number 070026 (the 26th order in July), to be arged to control number LP4208, required completion date July 8, cated in building 82F, written July 6, and available July 6. The job be done -- Repair Flow Controller (up to 24 spaces). After he is ·e of the correctness of this line of data he hits the return key on his inter, entering this data into the computer. He is ready to enter the ılance of his work order. His next data line would be similar to the llowing:

1-03-1-4-01-GASKET 001-2

The leading 1 indicates the sequence of the craft involved, strumentation (03), the number of men (1), the number of hours 4, the strument foreman's code (01) and the materials required (2) Gaskets 01).

If a second craft were involved a third line similar to the follow-g would be required

2-01-2-2-06

Sequence (2), to be scheduled after sequence 1 is completed. ·aft, electricians (01), two men (2) for two hours (2) by the electrical reman (06).

The computer program will file this data in all the required files ee Appendix B). Since there are materials required the scheduler will quest a material order by typing the following:

070026 - ORDER MATERIAL -

The program will search the parts file PAR III for work order 070026 nd print out on the stockroom clerk's printer the following information:

7 0026-1-03-001-2-GASKET-0708-LP4208-82F-01

he stockroom clerk knows immediately that the instrument foreman (01) needs wo (2) number (001) gaskets by July 8 to be charged to (LP4208) and delive o building (82F) tagged for job (070026). He checks his stock and finds onl ne (001) gasket. His supplier in Tulsa can deliver over night so he phones ne order to Tulsa and types the following data line on his printer:

07002 6-1-03 - 001 -2 - 01 - 0707 - 4

le has told the computer program that he has ordered (01) two (2) part umber (001) for sequence craft (1) on work order 070026, expects delivery uly 7, and cost is $4.

The next day the originator of the work order is concerned that his job vill be completed on time and calls the scheduler to confirm this date. The cheduler asks him to hold on for a second and types this data line on his rinter:

070026 STATUS

he computer receives this request, searches SCH IV for 070026 and does not ind it. Checking the parts file PAR III it finds that materials are on order nd expected to arrive 0707. Checking the start date (0708) the program rints out:

)70026 - WAITING ON MATERIAL - 0707 - 0708

The scheduler tells the originator "we had to order parts but you should be on schedule tomorrow" (0708).

Later that day (July 7) the express company from Tulsa delivers the quired material already tagged 070026 - 82F. The stockroom clerk places in the "hold" location for delivery to the job site the next morning and pes on his printer:

070026 - 1 - 03 -001 - 2 - 00

e has told the computer that the parts (001) for sequence craft (1) on job 07 e on hand. The computer deletes this work order from the Parts file and aces it in the schedule file and resorts that file to assure proper scheduling priority and desired completion date.

Around four p.m. that afternoon the scheduler types:

SCHEDULE - 03 - 0708

ie computer searches its Schedule File for Instrumentation (03) work orders ar ints them in order of their ranking in the file. One of the orders in the nking is:

070026 - 1 - 03 - 1 - 4 - 82F - 2 - 05 - 2 - 2

hen the schedule is completed the scheduler types:

MATERIAL - 03 - 0708

ie computer then prints a listing of all scheduled work orders with material quired on the stockroom clerk's printer. The clerk proceeds to put all aterials for these jobs on the delivery truck for delivery to the job site at 30 the next morning.

When the instrument foreman gets his schedule he notes that he is quence one (1) on job 070026 with an estimated (1) by (4). He sees that t ectricians are scheduled for 2 men 2 hours after he completes his part of e job (2-05-2-2). With this in mind he arranges for one of his instrument en to start the job at 8:00 A.M. the next morning.

The electrical foreman receives his schedule with the following

luded:

)026 - 2 - 05 - 2 - 2 - 82F - 1 - 01 - 1 - 4

notes that he is the second craft to be sequenced on the job and that trumentation has a (1) by (4) scheduled to proceed his electricians. He kes a note to schedule 2 electricians to 82F at 1:00 P.M.

The next morning (July 8) the instrumentman assigned to the job reports his foreman that the orifice in the flow meter had worn to the point it he couldn't calibrate the instrument and that he would have to order iew orifice. The foreman reports to the scheduler about his problem and ninds him that electrical has a 2 by 2 scheduled for that afternoon. The ieduler notifies the electrical foreman to skip that job and get another lower priority. He then types:

- 070026 -
- 03 --------------------------62041 - 1 - 0708 -

- 070026
- 03 - 1 - 2 - 01 -

0026 ORDER MATERIAL

has added one (1) part number (62041) to the work order, changed the mber 1 sequence craft hours per man to two (2), and requested the stockroor order the orifice.

Later that same day when the electrical foreman reports his jobs complet d his carryovers, he reports 070026 as carried over. The scheduler types:

0026 - C.O.-2-05 - 2 -2

e computer program will replace this sequence (2) electrical (05) work order (2) men (2) hours into the SCH IV file. Because it has a (2) sequence i not be rescheduled until 070026 - 1 - 03 - 1 - 2 is brought out of the

III file and replaced in SCH IV.

In the case where the warehouse happens to have the required component

ɔck the sequence of events could be:

26 - 1 - 03 - 62041 - 1 - ORIFICE - 0708 - LP 4208-82F -01

ed on the stockroom printer from the scheduler request above (- 070026

ER MATERIAL). The stockroom clerk, noting the required date equals that

date, would check immediately to see if he had the item in stock. Find-

t he would type:

26 - 1 - 03 - 62041 - 1 - 00 - 0708 - 40

26 - STATUS

second data line would result in the status report being printed by the

duler's printer:

26 - MATERIAL ON HAND - 0708 - 0708

instrument foreman would then arrange to have the orifice delivered to his

and proceed to complete his portion of the job. The electrical foreman

d complete his portion of the job and the scheduler's afternoon report to

computer would include:

070026 - 1 - 03 - COMPLETE
070026 - 2 - 05 - COMPLETE

computer program would remove both sequence crafts from the schedule

and store them in the completed work orders' file. Later in the month the

duler would request:

ɔRT - COMPLETED BY CONTROL NUMBER

ded in this report would be the following:

06 - 070026 - REPAIR FLOW CONTROLLER - 8 MANHOURS
- MATERIALS - $44 - COMPLETED ON SCHEDULE -

Summary

This proposed system will allow more efficient planning and scheduling aintenance operations by automating the routine functions of the job. The m design increases the responsibilities of the foreman and thereby gains effective use of craft manpower.

The system will also automatically accumulate management information the data entered by the system operators. These operators will require indoctrination but no special skills will be required so that present man- ɜr will be sufficient for operation of the system.

Elimination of present reports from the corporate computing system will ce the R&D contribution to the Computing Department budget by $6600. Th ly operating cost of the proposed system on the inhouse IBM model 1800 ;timated at $4000 for an annual savings of $2600.

CHAPTER V

Comparison of Present and Proposed System

To compare the present system and the proposed system required a simulation of parts of the proposed system. A teletype tape was punched with the data that the computer would supply the scheduler. These data were printed in response to specific request from the scheduler, he then typed his response with the entire process being timed. One day's receipt of work orders was used and timed individually to obtain the average time presented in the tables. The present system figures were obtained by measuring the elapsed time the scheduler used on the same work orders.

A logical comparison to make concerning the efficiency of the two systems is one involving the timing of events. The table below compares the total elapsed time for the scheduler to process the same typical work order under both systems.

TABLE VII

Scheduler Time Comparison

	Present System	Proposed Systen
New Work Order	42 sec	72 sec
Material Ordered	58 sec	62 sec
Material Available	10 sec	0
Scheduled	15 sec	0
Completed	5 sec	5 sec
Schedule Preparation	2.5 hours/day	5 min/day
Weekly Report	2.5 hours/week	10 sec/week
Total Elapsed Time/week at 30 W.O./day	20.5 hours/wk	6.5 hrs/wk

*Times were measured during a trial run of a typical day's work orders.

Also involved in the paper handling of the present system are the stockroor :s. They handle each work order three times and have numerous interruption day requesting information on delivery dates. Table VIII compares the time lved for the two systems.

TABLE VIII

Stockroom Clerk's Time Comparison

	Present System	Proposed Syste
Receive and File Work Order	10 sec	5 sec
Locate Work Order and Mail	20 sec	30 sec
Receive Work Order Requesting Delivery of Material	10 sec	5 sec
Total elapsed time/W.O.	40 sec	40 sec

The proposed system would have all information calls routed to the schedul in turn would request the information from the computer. The net result be less interruptions for the stockroom clerks - therefore greater efficiency that portion of the total operation.

With regard to effective utilization of manpower; there are provisions
lt into the proposed system that gives considerably more responsibility to
foreman. This has two desirable results. The foreman knows, on a
ly basis, about all jobs that are available for scheduling. If he has the
ortunity to work two or more jobs with the same crew, that would
nally be scheduled for only one job, he can gain considerably in his
ductivity. In addition under the proposed system, he no longer needs
scheduler to reassign his men in the event of a job shutdown or an
xpected rapid completion. He will have a full listing of available jobs
need only take the next highest ranked job and request material be
ivered to the job site. The foreman has ample opportunity to improve
manpower utilization and at the same time will take less of the scheduler's
e with interruptions.

The proposed system will have all information collected that is needed
all the management information reports that are now being generated
ugh multiple transmissions of work order copies to Computing Department.
addition to these reports already being generated, there is ample
ortunity to expand the system to absorb additional record keeping activities
hout addition of manpower or space. As a maintenance organization we car
ke much more effective utilization of our supervisory personnel by using them
analyze and evaluate our operations through the use of adequate records,
n we can by using them to generate reports for R&D management.

There seems to be a very definite cost savings in favor of the proposed
em in terms of computer cost. The total cost to R&D involves only the
litional equipment rental involved versus the direct savings to the R&D budge

An additional advantage to the proposed system is the inherent ɔtness of a machine printed schedule versus a hurried handwritten schedule. comparison of an actual daily schedule for the Instrument Section under the ᵎsent system and a schedule for the same day prepared by the proposed tem, can be made by comparing Figure IV and Figure V.

GROUP Instruments

W.O.NO.	CHARGE	LOCATION	WORK DESCRIPTION SUMMARY	HOURS SCHED	HOURS LEFT	
1.520	125	RM	Dec. PM 1x49		1X49	
2.661	1660	76G	[illegible] 2x90	2X8	2X82	
1.662	2457	83F	12/4 [illegible] T.C.	1X2		
1.499	3707	345 CL	12/4 Ewathom Temp. Controller [illegible]	1X4		Elliot to finish @ Noon -
1.72	126	[illegible]	Salvage Controller 1x3		1X3	
1.217	7001	81G	12/8 Repair Wheels (Navy) 1x3	1X3		
1.176	1400	248 CL	12/8 " timing unit 1x4	1X4		
1.588	3500	84F	12/8 " Wet Test meter 1x8		1X8	
1.608	3250	113.3	12/7 [illegible] on Evaporimeter 1x4		1X4	
1.609	3250	113.3	12/7 Repair Volt meter 1x4		1X4	
1.626	7001	81G	12/4 heater circuits on #1 [illegible]	1X3		
1.623	7001	81G	12/4 2000°F [illegible]	1X4		
1.625	2151	81F	12/4 Thermoelectric Temp. Cont. [illegible]	1X4		

Phillips Petroleum Company
Research and Development Department
Maintenance and Modification Work Schedule

: 12-4-73
ıp: Instrumentation
ɔower Available: 5 men 8 hours
: Available: In order of priority

: ɜr	Seq Code	Location	Work Description	Men X H
61	3	76G	140 Tray Column	2 X 8
62	2	83F	Build Thermocouples	1 X 4
·49	1	345RB1	Repair Temperature Controller	1 X 4
·17	1	81G	Repair Wheelco	1 X 8
76	1	268RB1	Repair Timer	1 X 2
·26	1	81G	Repair Heater Clock	1 X 2
·23	1	81G	Repair Taylor Fulscope	1 X 4
·25	1	81F	Repair Temperature Controller	1 X 4
·09	1	110RB3	Repair VTVM	1 X 4
·08	1	113RB3	Repair Evaporometer	1 X 8
88	1	84F	Repair Wet Test Meter	1 X 16
ı72	2	Whse	Salvage Temperature Controller	1 X 32
20	1	PM	December PM	1 X 64

ɜr Crafts Sequenced on Same Jobs

hanical:

·61	1	76G	140 Tray Column	4 X 4
·62	1	83F	Construct Thermal Wells	1 X 4
	3	83F	Install Thermal Wells	1 X 8

trical:

·26	2	81G	Re-install Heater Clock	1 X 1
ı72	1	Whse	Remove Temperature Controller	1 X 1
	3	Whse	Install Temperature Controller	1 X 1

FIGURE V

CHAPTER VI

Summary and Conclusions

A thorough search of current literature reveals an abundance of material cerning scheduling of all complexities. There is sufficient evidence ;ubstantiate the claim that computerized scheduling can improve operations ther they be production, delivery, flight plans, construction projects, even petroleum industry type maintenance. The strong points of some of systems studied were combined with the requirements of the maintenance anization at the Phillips Research Center into a proposed system for eduling of manpower and materials. The proposed system will use an sting central computer, currently being used exclusively for technical earch work, and two remote teletypewriters. The scheduler will enter all a required for operation of the system and for generation of weekly and ithly management information reports.

The proposed system will make use of the IBM 1800 computer now in :lusive scientific use, and two remote input/output tyepwriter units. The eduler will enter all data required by the system from the original work er, including materials to be ordered. The warehouse clerk will receive

material request from the computer and inform the computer of material
us. All information requests will be entered through the scheduler to
ɔce the number of outside interruptions the clerk must handle. The
em will generate a daily work schedule for each craft and include on this
ıtout all available jobs. The program considers job priority, material
ilability, and craft sequencing in generating this schedule.

The proposed system will operate at an annual cost of about $4,000 and
allow stopping the present expenditure of $6,600 for monthly reports
being paid to Computing Department. Additionally, it will free several
rs per month of supervisors' time now being used to edit and write
ɔrts. It has the potential to become an important tool for evaluation and
lysis of maintenance operations and to provide improvement in manpower
ization, materials handling, and eventually costing of jobs.

The only real question unanswered is the ability of the present scheduler
ɪdapt to the proposed system. His initial reaction has been favorable and
expresses a desire to try the system. It is the researchers' judgment that
can handle this system with very little practice with a typewriter. The
requirements are not great and he should have more time to apply to
coordinating efforts of the job.

It is recommended that the Maintenance and Modification Branch of Phillips
ɪarch and Development Department establish this system and evaluate its
ormance for a trial period. The only investment required would be about
man months' programmer time, to build and test the program. At that point,
equipment required could be leased on a monthly basis for an operating

luation. All programs and report formats would be tested and approved by cerned management before the operating trial period would begin.

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APPENDIX A

Maintenance and Modification Craft Scheduling

(Definitions-Formulas-Procedures-Exceptions)

tart Date

1. Definition - Start date is a machine calculated date for the total work order. It is the latest possible date that the first remaining sequence craft must be started in order to finish the job by the date required. Start date must be machine calculated every time any event or action changes a sequence, changes a craft, or adjusts hours per man on any sequence - craft record or changes date required on a work order.

2. Calculations - Start date equals date required minus time required to do the job (the sum of only the largest remaining hours per sequence for all sequences per work order divided by eight and rounded up) minus all Saturdays, Sundays, and Holidays plus one. Example: Assume date required is July 28, 1972, and the work order information is shown below:

W. O. No.	Sequence	Craft	Men Required	Remaining Hours per Man	
1234567	1	01	2	8	*
1234567	1	02	1	10	*
1234567	2	01	1	50	
1234567	3	02	2	5	*
1234567	3	03	1	6	*

Start date = July 28 minus (10+50+6)/8 = 8.25 =9.) minus 2 + 1 = July 18

*Two or more sequence crafts with the same sequence number must be performed at the same time. In these cases the hours should be equal but unequal hours will be allowed.

ıedule Sequencing (Sequence - crafts are scheduled as long as any craft man hours (men available times 8 hours) are available. A separate schedule will be generated for each craft.

1. Schedule all carry over (only one sequence - craft record) where start date is equal to or less than schedule date. Carry over sequence - craft records are in sequence by start date, date W.O. requested, priority, work order number, sequence, and craft. Try to schedule total hours remaining on the master file which is also equal to the hours in the carry-over file (usually not equal to the hours reported in the 'car' event).

2. Then schedule all sequence-crafts in sequence that can be scheduled in one eight-hour day for each word order in "start date cross index file" sequence (start date, date W.O. requested, priority, and work order number) where the start date is equal to or less than the schedule date. NOTE: If a sequence craft was scheduled in B.1. above and is encountered in B.2 eliminate that sequence-craft scheduled in B.1. and re-schedule it in B.2.

3. Then schedule all remaining carry-over records not examined in B.1. above. If a sequence - craft record was scheduled in B.2. and re-appears in B.3. ignore that record in B.3.

4. Then repeat B.2. for any remaining "start date cross index" word order records not examined in B.2. If a sequence-craft record was scheduled in B.3. above and is encountered in B.4. eliminate that sequence craft scheduled in B.3. and re-schedule it in B.4.

al Time Exception Notifications.

1. When a work order is entered or changed if the date required cannot be met based on calculated start date or date available on exception notice will be printed at the scheduler's terminal.

2. When the warehouse updates a parts record if the entered expected arrival date is equal to or greater than the calculated start date an exception notice will be printed at the scheduler's terminal.

her Comments.

1. No data will be carried historically.

2. Each man will only work eight hours per day.

3. No work will be scheduled on Saturdays, Sundays, or Holidays.

4. A sequence-craft record should be scheduled even if the parts required for a later sequence-craft record for the same work order number are not available.

5. Available work is work that could be scheduled if there were enough manpower available.

6. Sequence-craft jobs must be performed in the proper sequence.

7. Dates.
   a. Required (date job requested to be finished).
   b. Available (the earliest date work can be scheduled for this work order).
   c. Prepared (date work request processed).
   d. Material on order and expected to arrive at the warehouse.
   e. Start date (calculated - see A.).

8. Records on the carry over file are all sequence-craft records worked on today but not completed. These may be reported as carry over events reflecting those hours scheduled today, but not completed (in this case the hours on the carry over file will be total hours remaining for this sequence craft even though only scheduled but not completed hours were reported on the 'car' event); or they may be machine calculated if today's schedule was completed, but that particular sequence-craft was not completed (in this case the hours per man on the carry-over file will also equal the hours remaining even though no 'car' event was reported).

9. A sequence craft that was worked on yesterday but not today loses all "previously worked on" priority status.

0. Once a schedule event is requested the carry over file is eliminated.

1. Do not schedule a sequence-craft before the date available or until all parts are available for that sequence craft.

timated loads for cost estimates.

1. An average of 11-15 work orders per day (15 was used to adjust for changes). Assume this is also equal to the average schedule.

2. An average of 2 sequence crafts per work order.

3. An average of 7 parts per sequence craft per work order (events may be required for new, order, and receive).

4. A maximum of 90 days' work backlog.

5. Two manpower available updates per day.

6. Assume 25% of the total sequence craft schedule lines are carry over each day.

'. Assume one completed schedule event per day.

}. Assume one reprint schedule event per day.

?. Assume 10 worse case inquiries per day.

APPENDIX B

File Layouts

I. Work Order File

ber of tions	(7)	(1)	(3)	(24)	(4)
	(W. O. No.)	(Priority)	(Location)	(Job Description)	(Charge)

II Sequence Craft File

ber of tions	(7)	(2)	(2)	(1)	(6)	(6)
	(W. O. No.)	(Sequence)	(Craft)	(Priority)	(Available)	(Required)
	(6)	(6)	(2)	(2)	(3)	
	(Start)	(Requested Date)	(Foreman)	(Men Required)	(Remaining M	

III Parts File

ber of tions	(7)	(2)	(2)	(6)	(3)	(1)
	(W. O. No.)	(Sequence)	(Craft)	(Stock No.)	(Quantity)	(Availabilit
	(6)	(6)	(26)			
	(Expected Arrival)	(Start Date)	(Description)			

IV Schedule File

ber of tions	(2)	(4)	(7)	(2)	(1)
	(Craft)	(Machine Sequence)	(W. O. No.)	(Sequence)	(Priority)

(2) (3)

(Men Required) (Hours Per Man Scheduled)

AN V <u>Manpower Available File</u>

umber of cations	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
m	(Craft)	(Men)	(Craft)	(Men)	(Craft)	(Men)	(Craft)	(Men)
	(2)	(2)						
	(Craft)	(Men)						

AR VI <u>Carryover File</u>

umber of cations	(6)	(6)	(1)	(7)	(2)
m	(Start Date)	(Request Date)	(Priority)	(W. O. No.)	(Sequence)
	(2)	(2)	(2)		
	(Craft)	(Men)	(Hours per Man)		

A VII <u>Start Date Cross Index File</u>

umber of cations	(6)	(6)	(1)	(7)
m	(Start Date)	(Requested Date)	(Priority)	(W. O. No.)

APPENDIX C

File Update

Edits:

f action code equals "N" (New)

1. "U" Line - Priority (numeric), work order number (numeric) charge (alphanumeric - left justified), Date Required (numeric), location (alphanumeric left justified), date prepared (numeric), date available (numeric), job description (alphanumeric - left justified) all must be entered.

2. Line "1" - sequence (numeric), craft (alphanumeric left justified), men required (numeric), hours per man (numeric) and foreman's code (alphanumeric and left justified) must be entered.

3. Line "1" - if stock number (alphanumeric and left justified) is entered, then quantity (numeric and right justified) must be entered. If more line "1's" are needed to describe the parts required for a sequence craft enter a second or more line "1's" leaving columns 6-12 blank.

f Action Code Equals "D" (Delete)

1. Work order must be entered.

2. Sequence and craft may be entered to delete a particular sequence craft and all parts for that craft.

3. Stock numbers may be entered to delete parts within a sequence craft.

4. Quantity should not be entered.

If Action Code Equals "C" (Change)

1. Work order must be entered. Only enter other fields that are to be changed on the "U" line.

2. If a change is desired on line "1" sequence and craft must be entered. Only enter the other fields that are to be changed. It stock number is entered then quantity must be entered.

If Action Code Equals "A" (Add)

1. Work order number must be entered.

2. If a sequence craft is being added to a work order, then line 1 must be entered.

3. It a stock number is to be added to a present sequence craft columns 1-5 must be entered.

Other Edits:

1. Month must be less than 13.

2. Day must be less than 32.

3. Year must be greater than 72.

4. Craft must be M, E, I, W, or R.