OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D02728

Distribution:
LIMITED

ID/WG.99/66
6 August 1971

United Nations Industrial Development Organization

Original: ENGLISH

Second Interregional Fertilizer Symposium

Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item III/2b

ORGANIZING AND CONTROLLING MAINTENANCE IN FERTILIZER PLANTS[1/]

by

C. G. Barnes
R. S. Ray

Plant Operations Inc.
Santa Fe Springs - USA

1/ The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.71-6672

Distribution:
LIMITED

ID/WG.[illegible]/6 [illegible]
[illegible] July 1971

United Nations Industrial Development Organization

Original: ENGLISH

Second Interregional Fertilizer Symposium

Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item III/2b

SUMMARY

ORGANIZING AND CONTROLLING MAINTENANCE IN FERTILIZER PLANTS[1/]

by

C. C. Barnes
R. S. Ray

Plant Operations, Inc.
Santa Fé Springs USA

Today's trends toward large single-train ammonia plants surrounded by integrated units for further processing have increased the importance and complexity of maintenance. These trends have brought about changes in maintenance management that can be well applied to any segment of the fertilizer industry, new or old, simple or complex. The biggest single change was the move to more closely control and refine maintenance. The purpose of this paper is to simplify these controls and refinements such that they can be utilized by developing nations in keeping equipment functioning properly at the least cost and in keeping downtime to an economical minimum when downtime is necessary.

In order to upgrade maintenance in a given plant, it is necessary to analyze conditions in terms of need. Plants now operating may require the 'task force' approach in order to obtain immediate relief. This approach will be explaned in addition to the other factors that must be considered regardless of whether the fertilizer plant is operating, under construction, or planned for the future.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

After analysis has been made, progress can be made on setting up and equipping an effective maintenance organization. Of prime importance is the delineation of craft functions, defining of supervisory responsibilities, establishment of a training programme and utilization of planning, scheduling and cost control methods, and the problems of materials and tools choice and control. All of the aforementioned must be weighed carefully with respect to unique area condition such as local customs and politics and availability of manpower, shops, tools, materials, or training facilities.

Downtime prevention and downtime utilization should be given the highest priority when setting up a new maintenance organization or remodeling an old one.

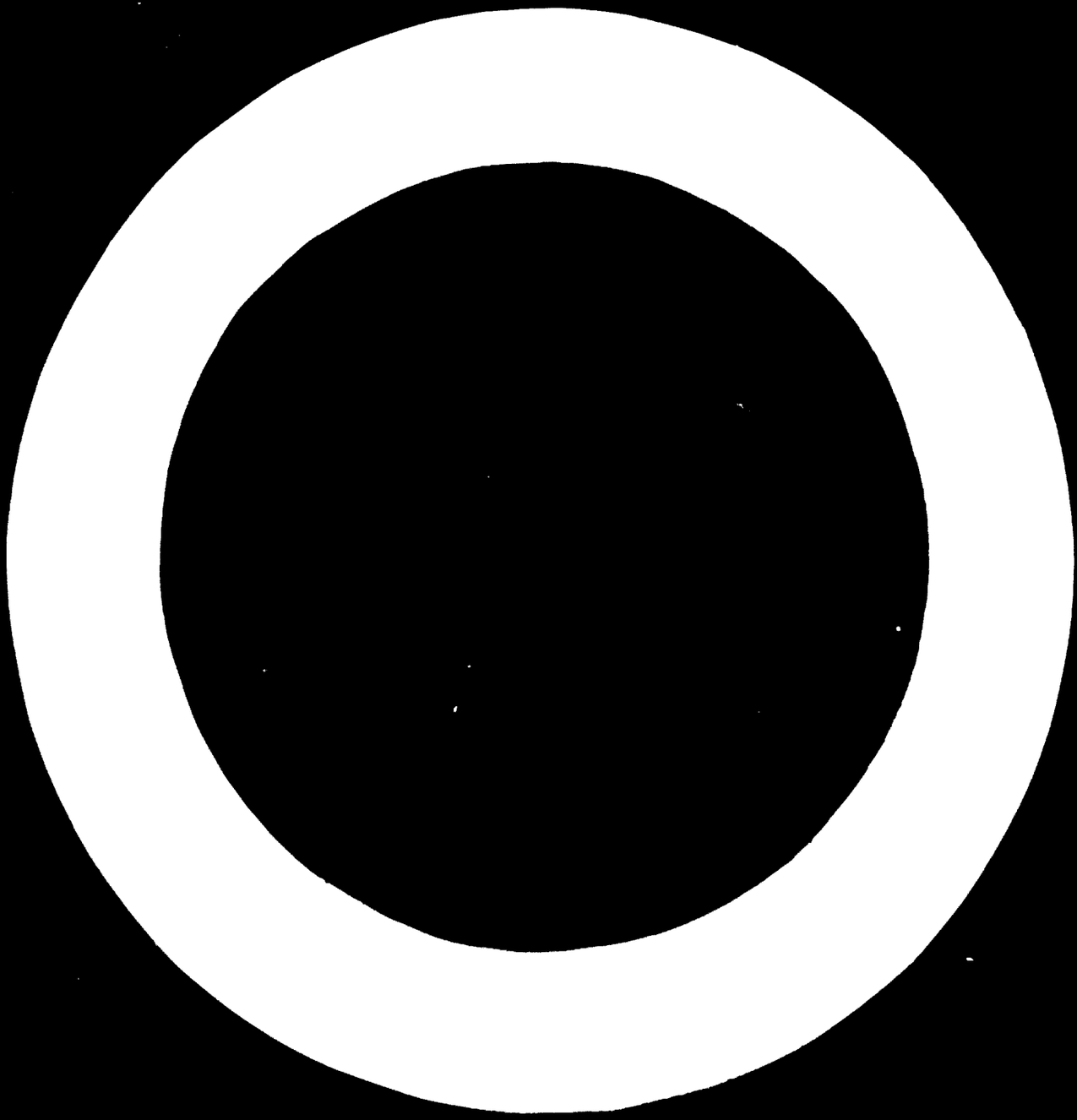
Downtime prevention necessitates a good "preventive or "predictive" maintenance programme one in which critical pieces of equipment are monitored such that trouble spots are found before they become failures. This can be accomplished through the training programme and through utilization of modern inspection tools and methods. This paper makes specific recommendations in this area.

Downtime utilization is extremely important in that an unplanned shutdown takes considerably longer than a planned shutdown. It is now possible to predict shutdowns in advance and prepare a simple set of plans that are variable. When an unplanned shutdown does occur, the fertilizer plant involved should be able to bring to bear on the problem a highly efficient, well-trained, and mobile group who will analyze and solve problems quickly. This group takes advantage of tools and materials planning which has been completed for a like situation. A simplified critical path can be on file which can be quickly altered to meet the particular need.

Developing nations should be aware of some of the repair problems found in the modern single-train fertilizer complexes as compared with the older type. Even though certain problems are basic, changes in process technology have required more complex equipment with subsequent increases in responsibilities of the maintenance group and therefore the need for better control. A discussion of various repair problems encountered in different types of fertilizer plants is useful because the need for control of maintenance functions and the occasional use of the task force approach is emphasized. Any specific problems presented will point up the need for a well-trained and efficient maintenance organization.

There is also an area to be discussed where process problems must be solved in conjunction with or sometimes prior to the solution of mechanical problems, likewise proper equipment operation sometimes becomes a critical part of the discussion and solution of mechanical problems.

CONTENTS



I. INTRODUCTION

1. The primary purpose of maintenance is to keep equipment running at low cost. This applies to all plants, but is of increasing importance with the advent of the modern single train plant with few installed spares. Complex problems have necessitated the refinement of the maintenance organizetion and pointed up the need for ever increasing control.

2. The intent of this paper is to develop a simplified approach to controlling maintenance, based upon actuel experience in the different types of fertilizer plants. It must be recognized thet there is no single way to organize, install and control a maintenance program that will fit all plants, wherever they might be. Each plant must take the program as presented and adapt it to its own particular needs and conditions. The program presented simply reletes what has worked best for us over the past 17 years, commencing with a two-train ammonia complex in 1954 and continuing to present experience with the single train complex. Since these plants were successful in regards to efficient maintenance, it would appear then that some value can be placed upon the practicel experience gained and in turn this might help others avoid dangers and pitfalls which can determine the success or failure of maintenance in a given facility.

II. REQUIREMENTS OF MANAGEMENT

3. Maintenance must have the backing of Management. Management must sincerely believe that a good program will maintain and improve equipment operating reliability, and in general achieve low-cost efficient maintenance through using a systematic method of analyzing work and laying it out in such a way that men, tools and materials and capital (hard currency, etc.) are used to greatest advantage.

III. ANALYZING FERTILIZER PLANT MAINTENANCE NEEDS

4. In order to determine the depth of maintenace improvement required at a particular fertilizer complex, it is necessary to review the situation as it exists. If the complex is in a planned stage, the same analysis can set maintenance policy. Following are factors to consider:

(1) Downtime - What type of breakdowns have occurred and what is the frequency? Are breakdown reports made? Is a corrective maintenance program in effect to prevent future occurrences?

(2) Manpower utilization - Over or under staffing. Is it necessary to staff maintenance people on a 24-hour day basis? Is excessive overtime necessary to complete daily work or on call-outs for repair? Is the daily work planned and laid out for the worker on a scheduled basis a day in advance? Is a training program used? Are maintenance department personnel responsibilities delineated?

(3) Materials, Tools, Shops and Equipment Utilization - Is the inventory of materials and tools sufficient and are shops and equipment adequate? Are they under control? Are they integrated into the planning of work?

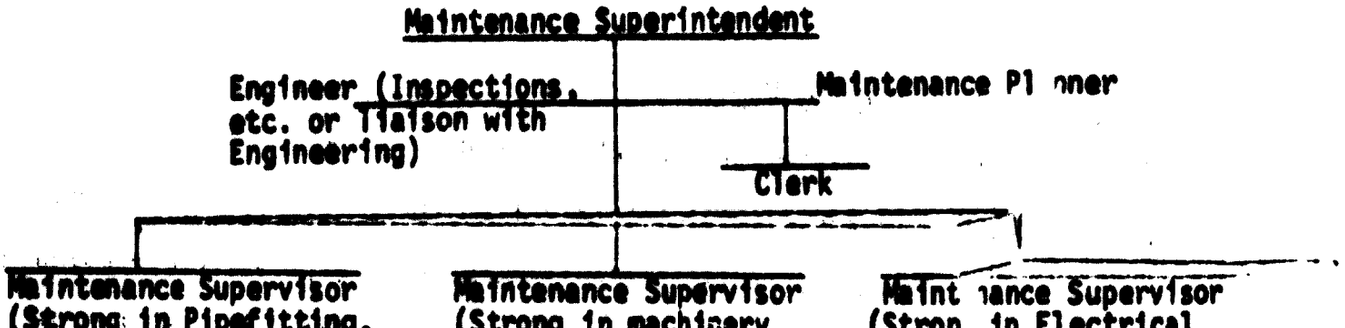
(4) Job Planning, Scheduling and Control of Costs - Can the effectiveness of the maintenance department be measured? Can costs be reported to management that justify budget recommendations? Can job progress be followed? To what extent is work planned and scheduled?

(5) Area Conditions - What local customs or conditions prevent organizing the maintenance department effectively? Is outside advice and assistance needed?

IV. SETTING UP THE MAINTENANCE DEPARTMENT

5. Again there can be no single organizational chart that can work for all fertilizer plants since local customs, unions, area conditions, etc. affect a

decision; however, the basic goal remains the same. The goal is to organize people into single or team effort with such responsibilities and team relationship that they can be productive and keep equipment operating with economic efficiancy. Of the varied types of maintenance organizations with which we have had experience over the years and the one that performed best in a $30,000,000 fertilizer complex, non-union with a centralized approach, was:



6. This centralized system will work well in a complex if the distance from the central shops to outlying areas, say the nitrate or urea areas, is not too far. If considerable travel time develops and if inefficient utilization of manpower, or poor communications between operations and maintenance result, then some of the good points of decentralized maintenance can be combined with this centralized approach to provide a flexible work force. The complex should then be split up into zones or areas and a maintenance supervisor and a limited number of craftsmen assigned to each zone or area, but retaining centralized planning if at all possible. Tool room-warehouse combinations should be located at each zone that will supply the needs for repetitive tools and materials used in the particular zone. The cost of stocking the additional warehouse will be more than paid for through better utilization of craft labor time.

V. TRAINING OF MAINTENANCE PERSONNEL

7. A training program must be simple, yet flexible enough to handle area

conditions where skilled manpower simply is not available, even on a contract basis. A program must be based upon the fact that a mechanic learns by doing since it is a fairly well accepted fact that a man remembers approximately 90% of what he does, 60% of what he sees and about 10% of what he is told. The main purpose should be to train front-line supervisory and maintenance personnel in safe working practices, design, operation and maintenance requirements of plant equipment.

Supervisory and General Training

8. The front-line supervisor is important because he represents direct contact with the people who perform the greatest volume of work. He must be given some sort of supervisory training which prepares him to properly communicate with the trainee. In general, better response and results will be obtained by first presenting training session subjects to the front-line supervisors and then using them to present the training courses to the maintenance personnel. Complicated and technical training sessions can be presented by company engineering personnel, equipment manufacturers representatives or certain companies now doing business world-wide in this field. Some general training sessions that have been used at a fertilizer complex are:

(1) Introduction to supervisory responsibilities.

(2) Maintenance safety practices for personnel and equipment.

(3) Maintenance tools - How to use them - Proper tools for every job.

(4) Maintenance materials.

(5) Alignment of equipment, procedures involved, tolerances allowed, interpretation of reading.

(6) Reciprocating compressors - valves, packing, clearances, wear, effect of rod run-out, lubrication, overhaul procedures, trouble-shooting procedures.

(7) Centrifugal compressors, turbines and pumps - design, operation and

maintenance, lubrication, clearances, trouble-shooting, overhaul procedures.

(8) Vibration detection - amplitudes, frequencies, tolerances, causes, interpretation of readings.

(9) Review of lubrication specifications - applications, limitations.

(10) Electrical motors and switch gear.

(11) Metals - application, corrision problems, solutions.

(12) Process vessels, boilers, reformers, exchangers, etc.

(13) Protective devices - pressure switches, temperature switches, relief valves, etc.

(14) Review and study of turnaround check sheets for major overhauls.

An effective program should have at least one training session each week. Detailed, exploded component drawings should be available for classroom training, as well as some actual equipment such as valves, pumps, etc. to disassemble and assemble.

Craft Training

9. The success of the craft training program centers around the performance of the supervisor and of qualified craftsmen as instructors. Costs involved in an on-the-job training program are low when controlled properly. There exists in any plant an optimum ratio of trainees to personnel that will satisfy the economic and personnel needs of the plant. It is the responsibility of the maintenance head to control this training ratio. Some basic rules are:

(1) Select trainees who have the desire and ability to become craftsmen.

(2) Prepare a training manual. A pipefitter manual, for example, will be broken down into sections as follows:

Safety

Hand Tools

Power Tools

Materials - pipe, flanges, fittings, gaskets, etc.

Layout work - Shop

Layout work - Field

Fabrication and Installation

Maintenance and Servicing - steam traps, etc.

Performance (When all the items in this section are signed off by another craftsman and supervisor, the man is qualified).

All sections of the manual should be illustrated pictorially with good use of exploded view, etc. and a minimum of reading.

(3) Prepare a technical library - This is obtained very easily in the form of equipment manufacturers service manuals or from those persons specializing in various crafts. An example would be "Modern Methods of Pipe Fabrication" used in most petrochemical plants and refineries in the U.S.A.

(4) Prepare a list of available schools if only correspondence schools. International correspondence schools have available a great many courses applicable to fertilizer plant maintenance. It must be recognized that language translation may be a problem in some cases.

(5) Require a simple training status report which compares hours required on various elements of the craft involved to hours completed.

VI. PLANNING AND SCHEDULING AS A MEANS OF CONTROL

10. The battle against high maintenance costs and excessive downtime is a continuing one. There is no single person better able to monitor the performance of the maintenance department than the Maintenance Planner. It is advisable in a fertilizer complex of the ammonia, urea, nitrate, nitric acid, solutions

type to create the position of Maintenance Planner or at least designate some one person who will absorb and utilize the following principles:

(1) Sound work request system (also known as work order).

(2) Planning and scheduling system.

(3) Cost control - With control, measures defined and job costs identified.

(4) Work backlog reporting and control.

(5) Maintenance records - Equipment history, costs, breakdown reports, etc.

11. This person needs not necessarily be one with a high degree of education; however, some additional technical training is desirable. A man from the craft ranks who has clerical ability, craft know-how and common sense normally will suffice as long as he has the necessary drive to continue learning.

12. Work Request System

It is absolutely essential that a work request (or work order) system be installed. Advantages are:

(1) Safety

(2) Job evaluation and priority.

(3) Job costing.

(4) Job history.

I know of no disadvantages since the small cost of printing and using the small form required are more than compensated for by improved manpower utilization.

13. A work request is a request for service from the maintenance department. A work request need not be issued for simple and repetitive jobs such as routine calibrations, inspections, etc. Calibrations, for example, can be listed on a sheet with space available for signing into and out of the area as a whole by the operator and craftsman. This makes the operator aware of work taking place in his area without individual sign-on and sign-off.

14. The basics of a simple work request are:

(1) Space for equipment identification.

(2) Space for description of work required.

(3) Space for accounting charge number.

(4) Space for requestor's name - approval.

(5) Space for availability of equipment.

(6) Work permit section for safe sign on and off the job by operator and craftsman.

(7) Space for summary of repairs by craftsman or supervisor.

15. Proper use of the work request permits the person planning work to determine the urgency of the job, schedule the important jobs for immediate attention and plan the remaining jobs in such a way that contract assistance and overtime will be kept to a minimum. All of the above, of course, requires close cooperation with and the approval of the proper persons responsible for various areas of the plant.

The Maintenance Planner

16. Primary functions of the Planner are:

(1) Receiving, coding, planning, scheduling and keeping machinery history on all properly authorized work requests.

(2) Establishing job standards including tools, equipment and materials for repetitive jobs.

(3) Reports to management that indicate how well maintenance is doing.

(4) Communications - liaison between plant departments.

Work Request Initiation

17. Anyone desiring work by the maintenance forces may fill out a work request form. Only the supervision of the department involved may approve it. The originator must supply the data required to describe the work to be done.

He should provide as complete a description of the work requested as possible and should indicate the symptoms if requesting repairs. Exact location of the job should be indicated and work such as valve packing, flange leaks, etc. will be tagged by person requesting work. Red numbered tags for shutdown work, green for running repairs. Tag numbers will be written on the face of the work request. The work request will be made in at least the original and one carbon copy. The operating force will route the original to their respective head for review and approval and will file the carbon copy. When the mechanic returns the original for a completion approval, the area operator will pull his carbon copy and destroy.

18. Any work request must also bear the signature of the supervisor authorized to approve maintenance work in the equipment identified on the work request. The person approving the work should be sure the form is filled out properly, i.e., unit identification, Plant location, tag number, etc. and that the completion date requested is a reasonable one, i.e., the latest date possible commensurate with the benefit to be derived by the Plant from the work requested. If the work request covers work in operating areas and is originated in the Engineering Department and/or the Maintenance Department, it should also be initialed by the operating supervisor in charge of the respective facility. These work requests (original and one carbon copy) are routed through the Maintenance Superintendent, Planner and then to the area operating supervisor.

Work Request Processing

19. The Maintenance Planner meets with operations coordinator (Superintendent or Supervisor) and reviews the work requests ready for issue at that time. These will normally be those written on the night shifts. The work request form is checked for proper approval and equipment identification, location

and work description. The work that the coordinator feels is of an emergency nature, and cannot wait until the next day to be scheduled, is given a priority date over the current schedule. Communications, problems or pertinent information of interest to both parties are exchanged at this time.

20. The Maintenance Planner then proceeds to the Maintenance Office where the jobs are discussed and checked for timing, job scope, etc. with the Maintenance Superintendent. The Maintenance Planner then processes all urgent or top priority work requests for that day and lists them by time, number and description on his daily pad (this is for record of interruptions to the planned schedule). He then has the work request ready for the Maintenance Supervisor to pick up when they deliver the previous day's time cards, etc. to the Planner.

21. The Maintenance Planner then processes all other work requests he may have received which have a later completion date and can be placed on the daily work schedule. He assigns the proper work request numbers and reviews the job as to material needed which may require ordering (these are sometimes referred to the Maintenance Supervisors). He estimates the approximate manpower needs, sequences the work request, should more than one Craft be involved, and does all he can to have the work complete by the recorded completion date on the work request in question. The Planner files these work requests in baskets designated for a particular maintenance group or, in the Maintenance Date File. These work requests are ready for scheduling. He keeps the work requests filed as to nearing completion dates and as to major type of work - pipefitting, machinery, etc., scheduling the work as much as possible to be completed on or before that date. He also must follow through on jobs that have stopped for one reason or another and push them through the schedule to completion.

22. If, while reviewing the work requests with the maintenance head, they are confronted with jobs of unusual complexity or magnitude, or abnormal material requirements, a Maintenance Supervisor or Engineer will be assigned at the morning report to accompany the Planner to the job site. It is also possible that the work request would be sent to Engineering. Here, decisions are made as to job requirements, material needs sequencing and manpower estimates and whether the completion date is a realistic one. The Maintenance Supervisors, Engineer, or Planner will fill out all requisitions for material and will notify the Warehouse if the material is required for the next day. New work of a capital nature may require Engineering and/or Managerial approval up to the top level, depending upon local rules.

Material Hold File

23. Should delivery of material be delayed or not in Warehouse stock, thus holding up the job, material requisition will come to the Maintenance Office with the work request form. The Maintenance Planner will assign the proper coding or work request number to the requisition, transfer his copy of the requisition to the work request in question and file the work request in his office "Material Hold" file. The approval requisition is delivered to the Warehouse for procurement. This file is checked daily, or as necessary, so that tracing of materials can be made if the receiving date is not met. Inquiry as to delayed materials are directed to the Supply Warehouse. When this material is received at the Warehouse, they will deliver to the Maintenance Office a material received form, which will list the work request number and requisition number of the material in question. The Maintenance Planner then pulls the corresponding work request for the Material Hold file and places it in the Maintenance Supervisor's work basket for scheduling. Engineering people are advised if the material received constitutes material

ordered by them.

Emergency Work

24. Urgent emergency requests for work are phoned into the Maintenance Office if at all possible. This type of work request must be approved in field by the respective operations supervisor. The Maintenance Planner will assign the proper work request number and notify the Maintenance Supervisor involved, and the Maintenance Superintendent if the work is relative to equipment of major importance. This work request will be picked up in the field, or may be written by the Planner. Emergency work requests shall be carefully evaluated to avoid interference with the daily scheduled work. Should the urgency of emergency work crowd out any particular important job, so as to interfere with its completion on the assigned day, the Maintenance Planner will refer this information to the Coordinator involved and they agree on a new date of completion or cancel some current work to release manpower, or hire contract workers if the job has such a priority. When the Maintenance Planner contacts a Maintenance Supervisor in reference to an emergency situation and it is found that manpower is not readily available, the Maintenance Planner will so indicate on the daily work schedule, a low priority job which may be stopped so as to provide men for the emergency work. All overtime work must be approved by the coordinator in charge of the facility requiring the maintenance work. The contact should be made by the Maintenance Planner. The daily accumulative record of emergency work is mailed to the Maintenance Superintendent and plant coordinators for their personal review.

Shutdown Files

25. Should a work request be classified as a shutdown job, the Maintenance Planner will review for material requirements, pre-fab work, etc. and place in a shutdown job file. He has a working shutdown file on each individual plant.

When advised by the operation coordinators that a particular plant is coming down, he will refer to these files and collaborate with the Maintenance Superintendent and plant coordinators on work to be assigned to the maintenance group. Usually the time factor involved will determine the number or type of jobs to be done. The Planner will then contact the Maintenance Supervisor involved for delivery of the work requests and pass on pertinent information.

Schedule Procedure

26. Shortly after mid-day, the Maintenance Supervisors will return their daily schedule marked up as a prediction sheet to the Planning Office showing how they predict the jobs will stand as to their completion at end of day. A total manpower forecast for the next day will be shown to indicate to the Planner any known absentees for that day. Emergency jobs received up to noon are written in on the prediction sheet. This sheet is routed to the Maintenance Superintendent for his personal review each day. To keep a continuity of the work, jobs not complete will be rescheduled by the Maintenance Planner the next day. Enough work is added from the craft work load basket to fulfill the manhour quota of the specific group. Should the job demand more attention than a normal crew can handle, the Maintenance Planner will shift manpower from other groups to assist. This may also become necessary in emergency situations or shutdowns. Extreme situations may demand the hiring of outside contractors. The Maintenance Planner will have all scheduling for the next day completed mid-afternoon. The master copy of the schedule for the next day should be in the Supervisor's Office with the required work requests before end of day. The schedule prediction sheet must be in the Planning Office early enough each day so that the above can be carried out as stated. The Maintenance Supervisors, upon receipt of the work

schedules and their return from the field, will:

(1) Review the work orders to familiarize themselves with the job details and special tool requirements.

(2) Plan in detail how to best accomplish the work scheduled for the following day.

(3) Assign men to the jobs scheduled.

(4) Communicate with the Maintenance Planner on any irregularities.

27. Upon completion of the work, the mechanic will have the work request signed off complete and return same to his supervisor, who in turn will check for dates, machinery history, manhours, etc., and route through the Maintenance Superintendent to the Planning Office. Work requests having pertinent information for file recording will be so indicated. When received by the Maintenance Planner, he will also review the information and record in the file all information underlined. All work requests are kept on file in the Planning Office. File cabinets carry current year, plus 1 year previous. Previous years records are kept in transfer files elsewhere. This completes the Planning Procedure for handling of work request forms.

New Equipment and New Permanent Work Request Numbers

28. When new equipment of any kind is added to any particular plant, it is evaluated by the Engineering or Maintenance Department and an identification number is set up. When decided, a list will come to the Maintenance Planner, listing the unit number and its particular service, manufacturer's model numbers and pertinent data to be posted on the file card. Maintenance Planner will then assign proper permanent work request numbers and ledger numbers, if necessary, to the units. The information follows a routine distribution routing, and is posted in all maintenance permanent work request number books. When in doubt as to the proper coding to use, clarification should be made by

the Accounting Group.

Hot Work Permit

29. Whenever a work request comes into the Planning Office and is found to fall into a HOT WORK PERMIT category (open flame or vessel entry, etc.) as differentiated from the normal work request permit, the Maintenance Planner will contact the Shift Supervisor and state the conditions of the work or leave him the work request in question. This is to be done whenever possible, 24 hours in advance of the actual work. The Shift Supervisor will process the HOT WORK PERMIT and route the work request back to Planning or Fire & Safety, if such a department is established. They shall further process and return a signed copy to the Planning Office. This copy is attached to the work request and the work is scheduled. Urgent work which cannot be scheduled in advance, is checked out and an emergency HOT WORK PERMIT is processed at that time on the job.

Material Hold Check

30. Each month the Warehouse will inventory all material in the "Material Hold" section. A list will come to the Planning Office asking for dispensation information. The Maintenance Planner will check this list against his own "Material Hold" file and indicate whether the job for which the material has been purchased is cancelled, still to be scheduled, or is awaiting a scheduled plant shutdown. The carbon copy is routed back to the Warehouse. In this way, the "Material Hold" file is kept up to date and active. This file must be reviewed often to avoid material delay on important work.

Manpower Analysis Report

31. At the end of each month, the Maintenance Planner must submit a Manpower Analysis Report. As a minimum, this report will indicate the total backlog of manhours on file by work request and a breakdown of the total as to craft

involved so that contract labor needs can be predicted for the coming month. Further progression into the field of maintenance labor and material costs can be made as economics dictate.

File Procedure

32. Completed work requests when routed back to the Planning Office will show up in the incoming mail basket. They are reviewed and all showing information underlined in red pencil by the Maintenance Supervisor are separated from those which will go directly to the work request cabinet file. Each work request is checked for proper signatures, manhours, jobs that are partially complete and each disposed of accordingly. The information as marked on the completed work request is transferred to a card in the file under the matching unit number and work request number, if desired. They are then filed away with the others in the file cabinet. Work requests are carried in the file for the current year and one previous year. When taken from the permanent file, they are boxed and stored for future reference.

VII. PREVENTIVE AND PREDICTIVE MAINTENANCE

33. Preventive maintenance implies making repairs before a piece of equipment fails. Predictive maintenance is the diagnosing of equipment while running in order to pinpoint trouble spots. Predictive maintenance, a relatively new term, has increased in importance in the single train ammonia plant with large centrifugal compressors, such that the two programs are administered together.

Preventive Maintenance

34. While each fertilizer plant must work out its own plan in line with types of equipment, management philosophy and maintenance personnel available, there are some general rules which apply to all:

(1) Identify equipment. This will naturally come about if a planning and scheduling system is involved.

(2) Determine what shall be done and how often. Qualified maintenance and process specialists are required who can make determinations based upon equipment manufacturers recommendations, experience and historical records. If such people are not available, they must be brought in from the outside. As stated there are those available whose business centers in this field.

(3) Set up a system of scheduling. This can be as simple as pre-printed work requests arranged in a file by month and day. Each day the Planner checks the file for the following day's PM work which must be placed on the schedule. The system can be placed on a Kardex-type flag system or tickler system where items are automatically flagged when due. PM scheduling can also be coupled to electronic data processing equipment which the print schedules and the feedback card actually used by the mechanic in the field. The data processing equipment digests the feedback cards after they have been completed and filled out by maintenance. A report is then forwarded, which becomes a useful tool in evaluating cost and performance of the program.

Predictive Maintenance

35. This type of maintenance is set up and scheduled with the preventive maintenance program. Predictive maintenance, however, should also be a day-to-day affair in a fertilizer plant and requires close cooperation with the operating group. The operators are in the best position to observe changes in pressure, temperature, noise levels, vibrations, etc. and should be trained and directed such that these are brought to the attention of Maintenance.

36. Typical predictive maintenance tools and their uses are:

(1) Vibration detectors - portable for mechanics intermittent use and permanently mounted proximity probes which detect shaft movement (very necessary on the centrifugal syn gas compressor).

(2) Vibration analyzer - to determine the source of vibration.

(3) Engine analyzer - onstream electronic analyzing of internal combustion engines and compressors.

(4) Ultrasonic corrosion analyzer - to detect loss of metal through corrosion or erosion.

(5) Electronic leak detector - capable of pin-pointing leaks that are difficult to pick up by soap test or other means. This has been especially useful to me in finding leaking reformer tubes.

37. All of the above equipment will require training of personnel in proper use. Personnel selected should be above average in intelligence, with the ability to reason clearly, write distinctly and with the ability to work on their own.

VIII. DOWNTIME UTILIZATION

38. The annual shutdown no longer should be considered a necessity and should be based upon analysis of critical equipment and economic considerations with ever increasing efforts to widen the time span. When fertilizer plants are confronted with an unplanned shutdown, they should be in a position such that as a general rule some prior planning has been done even though the exact nature of the shutdown was only pre-supposed some weeks or months prior from communications between operations and maintenance. A good downtime utilization program should be set up as follows:

(1) Good communications between process and mechanical departments of the Plant. At least one meeting a week where items that might shut the plant down are discussed.

(2) Listing of all shutdown jobs together with priorities.

(3) Repetitive jobs to be standardized and pre-printed complete with tool, material, services.

(4) Planner to keep all jobs in a planned state with a materials, tools,

services, planning sheet attached to each.

(5) Categorizing by operations and maintenance of shutdown possibilities into types, reformer tube failure, MEA cooler leaks, etc. and listing the shutdown jobs that would be done in each case.

(6) Manpower planning to be provided for each case with alternate methods provided, outside contractor, etc. An effort should be made to categorize, catalog and develop skills throughout the plant for use on shutdowns.

(7) Simplified critical path to be roughed out for each case.

(8) Continuing planning should be maintained for the plants major planned and scheduled turnaround in the event it is forced upon the plant early.

My experience has been that the shutdowns handled in this fashion have taken approximately 30% less time than those done before the program was initiated.

Critical Path Planning and Scheduling

39. So much has been written on this type of planning that details should not be necessary. A critical path approach necessitates breaking a shutdown down into all of the jobs of which it is composed, estimating then laying them out with arrow diagrams, indicating the sequence in which jobs are done. The critical path is the longest path in time through the diagram system. The jobs in which a delay for any reason would result in a delay in the shutdown are known. Keep the critical path simple and lay it out with the days of the week listed at the top, with shift start and stop times indicated. If these things are not done, the critical path becomes difficult to interpret and will not be followed willingly by the people supervising the work.

IX. TASK FORCE SOLUTION TO PLANT PROBLEMS

40. Fertilizer plant repair problems are somewhat similar in nature, whether

the plant be old or new, but the impact is felt more with the new single train units where the entire production can rest more upon single pieces of equipment. The newer plants, in general, operate with less maintenance people, engineers and operators, and are not normally staffed to handle complex problems. With this has come an increasing dependence upon outside help.

41. Because of manpower economics within the fertilizer plant, coupled with the fact that equipment manufacturers do not normally feel the basic responsibility nor do they have the incentive to provide the prompt technical service required, the task force approach was developed and used successfully at plants with which I have been associated.

42. A highly efficient, well-trained and mobile group of specialists, both process and mechanical, must be created or developed from existing personnel. In this case, since we were a multi-plant operation, the choice was simpler. Certain key men were found in the various plants and home office who met our needs. When the fertilizer plant needs were defined or when an emergency occurred, these men left their normal duties and concentrated on the ammonia plant, for example. This relatively small group of mobile, technical specialists became the key to better plant performance and costs.

43. Consideration should be given this approach to complex problems facing the fertilizer plant in any country. If the task force cannot be derived from within the plant or within the country, then use should be made of those outside contractors who are able to supply the specialists on a world-wide basis. Quickly interjecting into the critical problems, the best technical specialists regardless of where they are from is usually the most economical solution.

44. Recent problems solved by the mechanical section of a task force group are:

(1) Most economical method of changing out primary reformer tubes.

(2) Most economical method of changing reformer catalyst.

(3) Improved design for primary reformer transfer main header.

(4) Improved insulation for reformer lower header.

(5) Reliable vibration probe installation on centrifugal compressors.

(6) Most economical method of changing out high pressure primary waste heat boiler bundle.

(7) Elimination of frozen couplings on centrifugal syn gas compressor.

X. CORRECTIVE MAINTENANCE AFTER REPAIR

45. Often times the solutions to a repair problem lies somewhere between mechanical and process groups. Close cooperation between these groups is essential when problems arise. A very significant reduction in failures has been noted when the realization was made that equipment had not been operated properly and that operating procedures or process conditions would not permit a permanent solution to the problem by maintenance.

46. Mechanical and process groups must work jointly to:

(1) Prepare start-up procedures for critical equipment.

(2) Prepare start-up check lists.

(3) Prepare emergency or shutdown procedures for critical equipment.

(4) Review the machinery history files, corrective maintenance reports.

(5) Set up inspection schedules, especially regarding corrosion rates.

47. Corrective maintenance implies the analyzing of a breakdown or repair and subsequent solution to avoid repetition. All equipment breakdowns should be reported and investigated following this general procedure:

(1) A breakdown report is made while the repair is being made or as soon as possible thereafter by the Maintenance Supervisor. Essential items are equipment number, description, location, problem, repairs made, sugges-

tions, and space for joint resolution by mechanical and process groups of corrective maintenance required.

(2) Copy to Plant Manager, maintenance, operations, and engineering departments.

(3) Breakdown review by engineering and maintenance departments.

(4) Filing of report in maintenance office.

(5) Follow-up on corrective maintenance by assigned person or persons.

XI. SPARE PARTS

48. The goal of any effective spare parts program is to keep the investment to a minimum without seriously jeopardizing the plant on-stream factor and to administer the program at the lowest possible costs. Modern single train plants with few installed spares are hard-pressed to meet this goal because of the necessity for more rapid response to a breakdown, plus the higher costs for a large single piece of spare equipment, syn gas compressor spare rotating assemblies, for example.

49. Each critical piece of equipment in the plant must be analyzed as to necessity for:

(1) Installed spare.

(2) Shelf spare.

(3) Reliance on vendors emergency delivery.

(4) Ability to reproduce the spare locally or elsewhere.

(5) Cost of shutdown in above cases.

(6) Probability and frequency of failure determined from vendors viewpoint, other plant experience, plant maintenance experience and specialists contracted from outside if necessary.

50. Plants with which I have been associated have had success in sharing in a common spare parts pool with other companies who have related plants. This

reduces the capital outlay considerably while lessening the risk to some extent. We did this with expensive high-pressure turbine rotors and centrifugal compressor rotating assemblies and have considered sharing spare synthesis converter baskets. If this cannot be done, it is advisable to negotiate spare parts as part of the original purchase when dealing with competing vendors. We have reduced overall costs greatly in this manner.

51. If a plant is located such that it has virtually no access to spare parts or spare parts repair, it is obvious then that its capital outlay will be greater. Increased size of shops, amount of equipment and training of personnal may be the only answer since many times a maintenance department with a little ingenuity can repair or reproduce a part equal to or better than the vendor. An example of this is the first nitric acid plant with which I was associated. We discovered cracks in all five impellers, in the second case of our two 9-stage centrifugal air compressors. After having installed the spare rotating assembly, we found that delivery on another assembly was 11 months. Through careful selection of forgings, use of a 3-dimensional milling machine and using the hydrogen furnacebraze technique for joining of cover plate to vanes, we were able to reproduce the impellers in four weeks of a better material and quality. This simply indicates what a maintenance department can do it it has the determination.

52. Basic requirements for control are:

(1) Classification and identification of spare parts.

(2) Records system, Kardex for example, for keeping a permanent record of vendor, part number, withdrawals, etc.

(3) Activity report for cost control.

XII. REPAIR PROBLEMS

53. Listed below are some miscellaneous repair suggestions that might be of

value. Space is not available for the details that I would like to provide; however, the listing may stimulate questions that would be answered upon request:

(1) Repeated loss of radial bearings has occurred on centrifugal syn gas compressors. Changing from the sleeve type to tilting pad type should correct the problem if cause was from oil whip.

(2) Locked or frozen high-speed couplings will occur on the new centrifugal compressors if oil in the console is not kept free of water and dirt. Addition of a centrifuge to the lube oil console is recommended as locked couplings cause severe vibration and resultant damage.

(3) It is advisable to install high oil temperature alarms on all thrust bearings on centrifugal air, ammonia and syn gas compressors. A reliable proximity probe should be used as a thrust indicator rather than that supplied with the equipment.

(4) Intercooler leaks on centrifugal compressors result in build-up of deposits on impellers and in many cases have resulted in severe damage. A program to minimize failure is as follows:

i. Pressure and temperature indicators on inlet and discharge side of each impeller stage.

ii. Interstage pressures, temperatures, bearing temperatures and vibration readings to be recorded on shift basis.

iii. Inspect condensate drains and bypass for proper operation on a shift basis. Excess condensate could indicate a leak.

iv. Take condersate samples on a regular basis. Develop test to tell difference between condensate and cooling water (pH, color, etc.)

v. Train operators and maintenance people to be alert to change in operating conditions.

(5) Urea plant reactor letdown valves normally crack or erode. A very successful valve now used is Annin Model 7461.

(6) Urea plant high-pressure carbomate pumps often have rod packing problems. Use pressure formed teflon asbestos braid. John Crane Co. Style 207 is good.

(7) Urea plant valves in carbomate service should have pure teflon braid, Chesterton Style 28, for example.

(8) Fertilizer solids handling belt bucket elevators should be equipped with electrical motion switches so that if the belt is overloaded in the pit and stops, the drive end will not turn inside the belt and ruin it. Euclid switches are good.

(9) Tack weld all the nuts on chain and sprocket bucket elevators - nothing else seems to work. Best bearing for bucket elevator pit is Dodge, double interlock, special duty.

(10) Make sure that all electrical conduit in corrosive areas - nitrate, etc., are tightly made up with teflon tape and preferably are plastic-coated.

(11) Hammer mills in corrosive, dusty areas should have mist lubrication systems to prevent frequent bearing replacements. Best bearings for hammer mill in corrosive service is Dodge, Type C, pillow block.

(12) All things considered, the spiral wound gasket - Flexitallic, for example, seems to solve more problems than any other type.

(13) If you cannot train your operators to properly take up pump packing, have them leave it to maintenance. Needless maintenance expense will result without proper training.

(14) Discourage maintenance people from operating valves, clearing pumps for work etc. Use the work request system and leave it to the operator.

(15) Use operators on major shutdowns as maintenance helpers. It pro-

motes mutual understanding and they normally take better interest in the job.

(16) Urea plant pump mechanical seals should have some automatic method of turning in steam well ahead of pump start.

(17) Sulphuric acid pumps - a good mechanical seal is now available that has indicating pins to show wear - Chesterton, for example.

(18) Use acid resistant brick in sulphate, nitrate, etc. areas wherever economically possible. Concrete simply does not work well.

(19) Make sure that strip heaters are automatically kept on when large electric motors are down. Megger if down for more than one day and exposed to dampness.

(20) High pressure jetting of heat exchanger bundles has proven to be the most satisfactory cleaning method on an overall basis.

(21) Order test heads as part of heat exchanger purchase.

(22) A good preventive maintenance program is necessary on automotive equipment in the solids handling areas - diesel equipment is preferable.

(23) In large storage areas the front-end loader should have overhead protection for the operator. Injury or death can result from caked product tumbling down.

(24) Be sure you have a clearing and tagging procedure for use in repair. For example, when a mechanic works on a pump, the switchgear should be locked out and/or tagged by both the operator and the mechanic.

(25) Adequate drainage is not normally provided in sulphuric acid plants. Consider this when building a new plant.

(26) Wound fibreglass pipe - Bondstrand, for example - works well in phosphoric acid service. Ends must be cut square, however, and kept clean before joining. The cement used Weldfast 220 is also good for metal repair - tanks, etc.

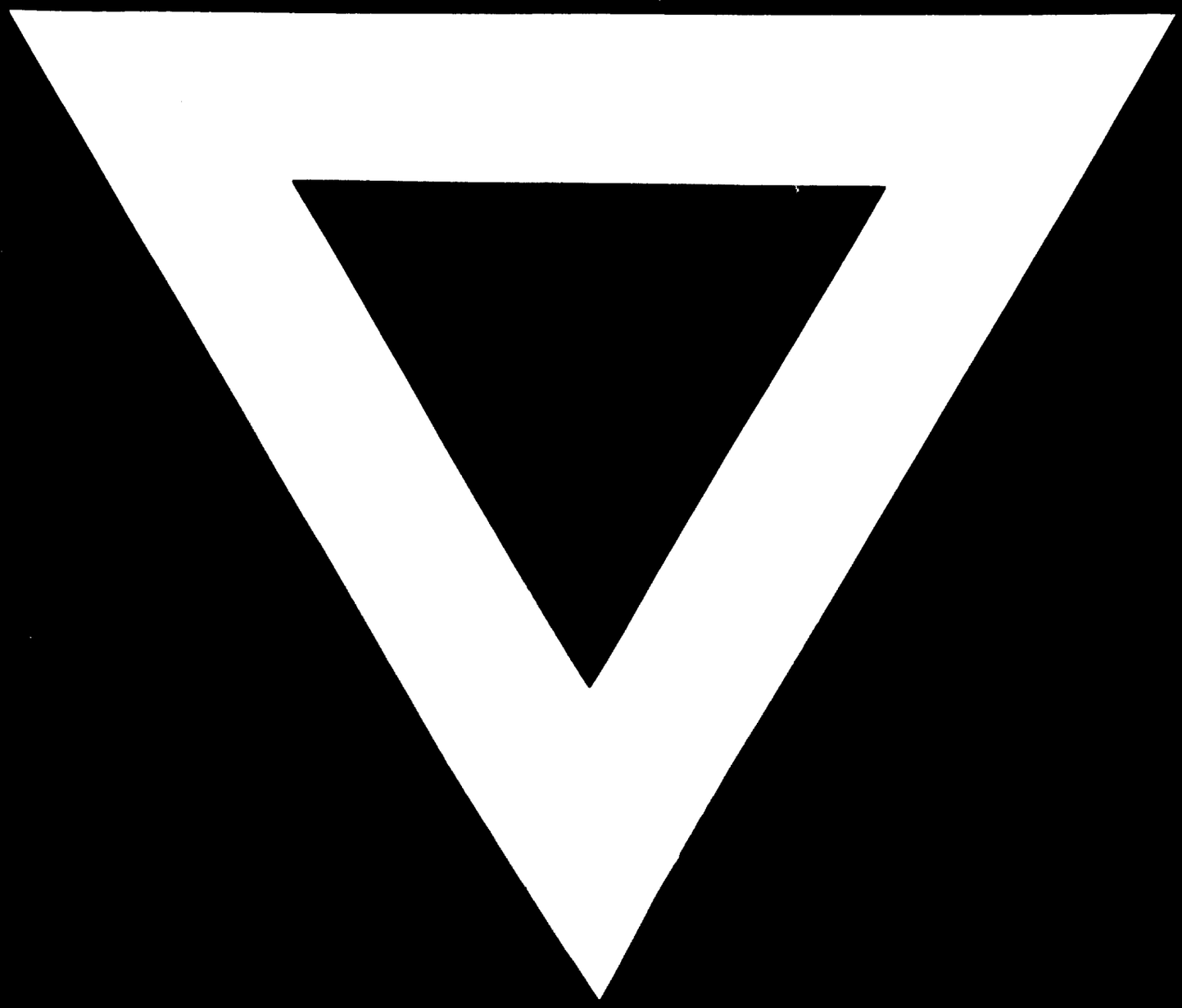
(27) Leaking synthesis converter, or other high-pressure heads, especially on the older units, can be corrected by proper installation of gasket and make up of bolts with a 33 to 1 ratio Sweeney Powerwrench and anchor plate.

(28) On vertical pumps, ammonia, etc. where the bearing lubrication is supplied from the liquid being pumped, Graphalloy (babbit filled carbon) bearings work very well.

(29) Many failures have occurred as a result of water seepage under the foundation plates of motors, speed increasers, etc. This causes corrosion and subsequent "growth" and misalignment of equipment. Foundations should be sealed with an epoxy such as Ceilcote EJ-3.

XIII. CONCLUSION

54. Bear in mind that you will get out of maintenance that which you inject into it. It must have management backing and understanding and must be treated with respect. It must consist of a sound organization of well-trained people with responsibilities defined. These people must be given the system and the tools to carry out their duties. Performance must be monitored and adjustments made as necessary to achieve the primary objective of keeping equipment running at low cost.



14. 3. 72