A STUDY TO DETERMINE THE BEST OPERATING AND MAINTENANCE PROCEDURE FOR A 200,000 POUNDS PER HOUR STEAM GENERATING PLANT

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Fred Arthur Woolman

1950

This is to certify that the

thesis entitled

A STUDY TO DETERMINE THE BEST OPERATING AND MAINTENANCE

PROCEDURE FOR A 200,000# PER HOUR STEAM

GENERATING PLANT

presented by

Fred A. Woolman

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Mechanical Engineering

O. H. Pesterfield
Major professor

Date December 4, 1950

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A STUDY TO DETERMINE THE BEST OPERATING AND MAINTENANCE PROCEDURE FOR A 200,000 POUNDS PER HOUR STEAM GENERATING PLANT

by

FRED ARTHUR WOOLMAN

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Mechanical Engineering

1950

South Campus Power Plant

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ACKNOWLEDGMENT

The author wishes to thank Professor J. M. Campbell, of Michigan State College, and all the power plant personnel for their valuable assistance and cooperation in obtaining the necessary information and preparing the manuscript.

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FOREWORD

by

MR. J. M. CAMPBELL

Superintendent of Power

Michigan State College

Mr. Fred Woolman has been employed by the Department of Buildings and Utilities of Michigan State College since March 1948, with the title of Assistant Mechanical Engineer and with duties in the college power plant aimed at a system of improved maintenance and operation of the plant equipment. It is considered that Fred has given a good account of himself in this capacity and should, therefore, have a basis for contributing to the over all knowledge on the problems of Power Plant Maintenance and Operation by means of this thesis.

J. M. C.

Fig. 1

South Campus Firing Alley

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INTRODUCTION

As steam generating plants become larger and the machinery is more complicated, the need for better trained supervision and plant personnel is warranted. The ultimate objective is low cost, efficient and continuous services, producing steam below the cost of purchased steam or other suitable power.

With the competition between low cost steam of central steam generating plants and the production of own steam generation being very great, the small plant must be run as cheaply and efficiently as possible.

The most suitable location of a plant is chosen. The architect and consulting engineer design, build and place the machinery and tools with which the plant engineer has to work. From here it is his job to see that operating costs, plant efficiency, and reliability are obtained.

It is hoped that this thesis will act as a guide to the supervisors of small steam plants to increase plant reliability, efficiency and reduce over all cost of steam generation to below that of purchased steam.

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Part I

THE PLANT

The steam generating plant used for this study is the new south campus plant at Michigan State College. This building is located on the south campus of the college a few hundred feet southeast of Macklin Stadium and just north of Shaw Lane. See map, Fig. 2, page 7.

Excavation for this plant began on October 10, 1946 and initial operation took place December 8, 1947.

After approximately on year's operation (March 1949), this study to determine the best operation and maintenance procedure was begun. It covers the period from March 1949 through September 1950.

To produce steam in sufficient quantities, and so to be reliable, efficient, and economical at all times as to warrant continuous operation is the plant objective.

REASONS FOR NEW SOUTH CAMPUS PLANT[1]

Immediately after the war in 1946 when college enrollment had greatly increased, existing college facilities had to be increased. Thus, to keep up with this increase in demand, (see Fig. 3, page 8), it became apparent that either larger steam generators must be installed in the existing plant or a new steam generating plant must be built including steam transmission line to the existing turbine room and steam dis-

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1. Information was obtained in an interview with Mr. E. E. Kinney, Superintendent of Building and Utilities, Michigan State College.


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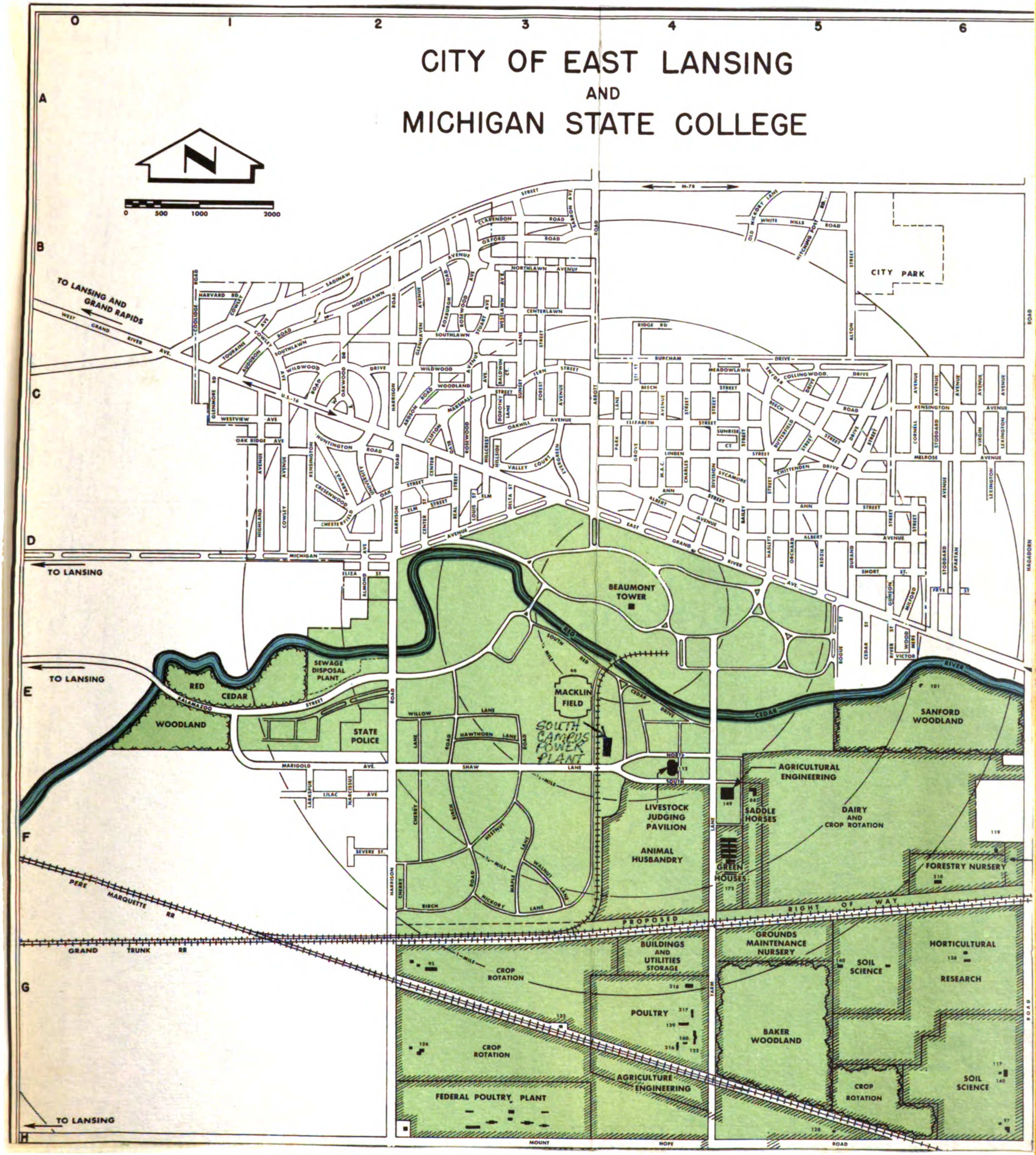
Fig. 2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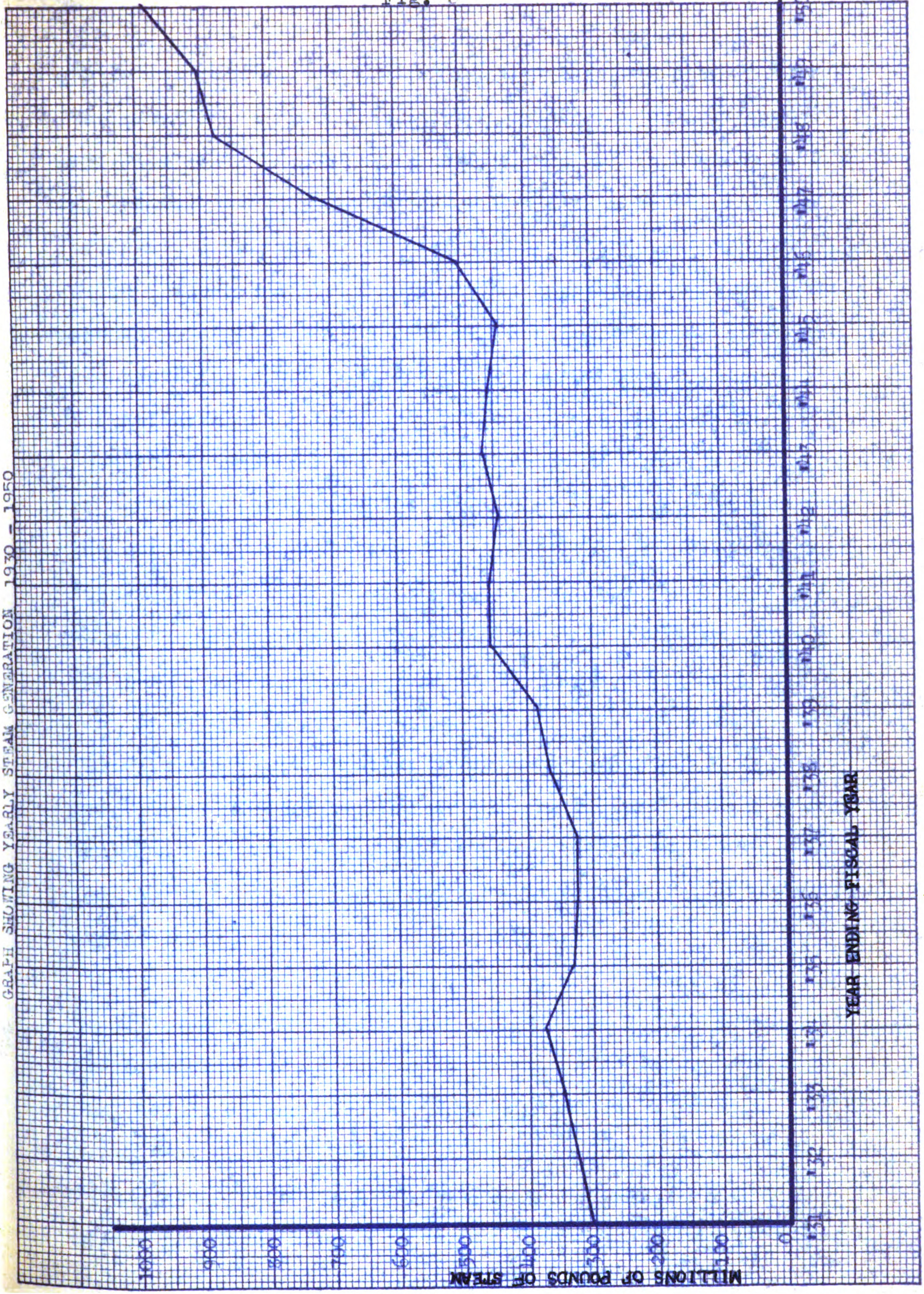
SEWAGE DISPOSAL PLANT
RED CEDAR WOODLAND
STATE POLICE
MACKLIN FIELD
SOUTH CAMPUS POWER PLANT
AGRICULTURAL ENGINEERING
LIVESTOCK JUDGING PAVILION
SADDLE HORSES
DAIRY AND CROP ROTATION
SANFORD WOODLAND
ANIMAL HUSBANDRY
GREEN HOUSES
FORESTRY NURSERY
CITY PARK
PROPOSED RIGHT OF WAY
PERE MARQUETTE RR
GRAND TRUNK RR
BUILDINGS AND UTILITIES STORAGE
GROUNDS MAINTENANCE NURSERY
SOIL SCIENCE
HORTICULTURAL RESEARCH
CROP ROTATION
POULTRY
BAKER WOODLAND
CROP ROTATION
AGRICULTURE ENGINEERING
CROP ROTATION
SOIL SCIENCE
FEDERAL POULTRY PLANT
MOUNT HOPE ROAD
MICHIGAN AVE
GRAND RIVER AVE
HARRISON ROAD
HAGADORN ROAD
FARM LANE
SHAW LANE
KALAMAZOO STREET
RED CEDAR RIVER

Fig. 3


GRAPH SHOWING YEARLY STEAM GENERATION 1930 - 1950
MILLIONS OF POUNDS OF STEAM
0
100
200
300
400
500
600
700
800
900
1000
YEAR ENDING FISCAL YEAR
'31
'32
'33
'34
'35
'36
'37
'38
'39
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'41
'42
'43
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'49
'50

tribution center. Also, on account of costs it was out of the question to re-locate the turbine room with its steam and electrical distribution center.

Since the existing building would have to be enlarged or rebuilt, because of the difficulty of interrupting service while the new boilers were being installed, and due to public sentiment against the storage and burning of coal in greater quantities in a central part of the campus, the latter plan was followed.

The question of how far away and where the plant was to be built was settled in two ways. That is, it had to be near the existing railroad spur and the distance had to be within economical limit of steam transmission. Thus, the present site was chosen, making the steam transmission line 1500 feet long.

As a 3000 kilowatt turbine generator was installed in the existing plant in 1941, with an operating pressure of 300 psi, it was decided to install 300 psi boilers. Two of these boilers, each producing 110,000 pounds per hour, were installed. A third bay for an additional boiler was left for future expansion.

PLANT STRUCTURE

The design of the building is such as to fit in with the architectural pattern of existing buildings on the campus. That is, it is constructed of red brick with precast concrete trim. The roof has a pitch of 45 degrees and is constructed with precast concrete slabs which are covered with gray asbestos shingles. Also, the stacks (one for each boiler) pro-

trude above the peak about 18 inches to give a conventional chimney effect.

Over all building dimensions are 127 feet 7 inches by 61 feet 10 inches, and 77 feet 7 inches above grade line. The interior consists of three boiler bays, an electrical and feed water pump bay, a water testing laboratory, maintenance room, and office.

Interior color scheme used in this building is as follows:

Gratings, Stairs, Pipe Railings	Pewter Gray
Boilers, Pumps, Fans	Vista Green
Coal Conveying Equipment Ash Conveying Equipment Air Ducts Steam and Water Piping Doors and Frames	Laurel Green
Ceilings	Cascade Blue
Control Boards except Dark Green Base	Suntone
Concrete Bases for Motors, Bases and Fans	Diamond Yellow
Valve Wheels and Important Spotting	Focal Red
Structural Steel	Power House Buff
Floors	Blue Gray
Alley-ways	Tile Red

PLANT DISCUSSION

With all facilities for steam distribution, that is, bleeder turbines, distribution piping, condensate collection, and water softening equipment already installed, it was considered more economical to continue to enlarge these facilities as necessary rather than move to or install comparable new devices in the south campus plant. Therefore, it is felt necessary to discuss the steam-water cycle.

Steam at 300 psi and 550°F. is transmitted through two lines (an 8 and a 12 inch) of "Ric-Wil" underground piping 1500 feet long to two 3000 kw. turbines in the turbine room in the north campus plant.

These turbines have extractions at 100 psi and 5 psi. Also, steam may be reduced from 300 to 150 psi and desuperheated through a reducing station when the steam load is above capacity of the turbine extraction. However, this method is only used in emergencies or as stated above.

The 100 psi extraction is used for process steam and long distance heating, while 5 psi extraction is used for central campus heating.

All returning condensate from the heating returns is collected in two condensate storage tanks and pumped to the deaerating heater. Also, if the turbines are operated entirely condensing, this condensate is pumped directly to the deaerating heater.

Here, also, the feed water make-up is added. The make-up is a blended sodium, hydrogen zeolite softened water, consisting of about 20% sodium to 80% hydrogen. In normal operation the make-up runs about 15 to 20%.

From the deaerating heater the water is pumped to the south campus plant storage tank.

At this point, in case of failure to receive feedwater, a raw water connection is maintained. However, this line is kept completely closed and is used in emergencies only.

PUBLICITY

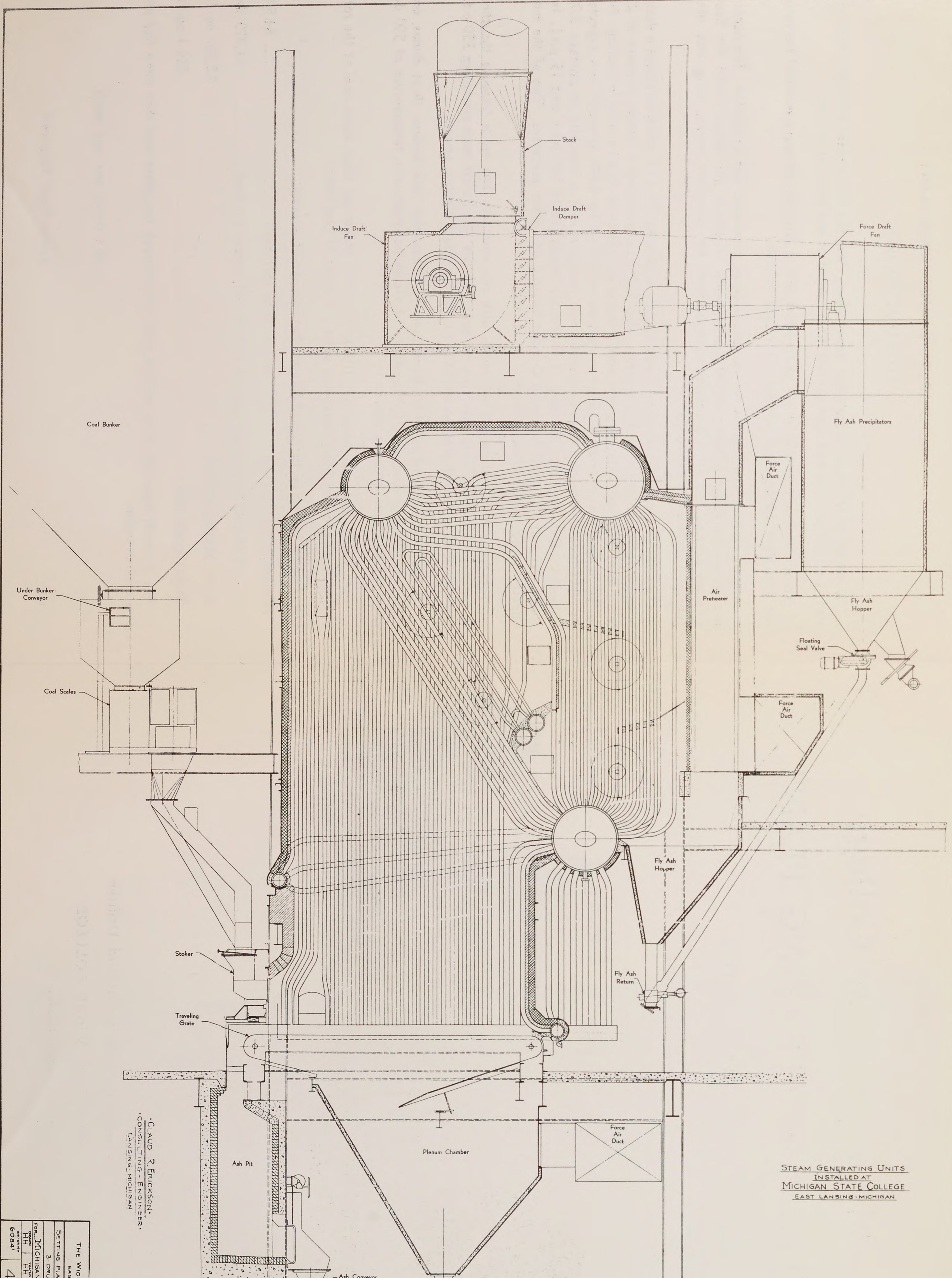
It is felt that because the plant is owned and operated by state funds that a small publicity pamphlet describing the plant should be used and distributed to all visitors. One of these pamphlets is shown in Fig. 4, page 13.

PLANT PERSONNEL

The plant personnel consists of 2 full time salaried and 14 full time hourly employees. Also, from 4 to 6 part time help (students) averaging about 10 hours per week are employed.

This is broken down as follows:

- Plant Engineer
- Asst. Plant Engineer
- Laboratory Technician (1)
- Utility men (2)
- Electrician (1)
- Crane Operator (1)
- Coal Handling (1)
- Custodian (1)
- Firemen (4)
- Asst. Firemen (4)
- Painters, part time (2)
- Utility Helper, part time (1)


Stack
Induce Draft Damper
Induce Draft Fan
Force Draft Fan
Coal Bunker
Fly Ash Precipitators
Force Air Duct
Under Bunker Conveyor
Air Preheater
Fly Ash Hopper
Floating Seal Valve
Coal Scales
Force Air Duct
Fly Ash Hopper
Stoker
Fly Ash Return
Traveling Grate
Force Air Duct
Plenum Chamber
Ash Pit
Ash Conveyor
·CLAUD R. ERICKSON·
·CONSULTING - ENGINEER·
LANSING - MICHIGAN
STEAM GENERATING UNITS
INSTALLED AT
MICHIGAN STATE COLLEGE
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SETTING PLAN FOR 1 OF 2-1420 H.P.
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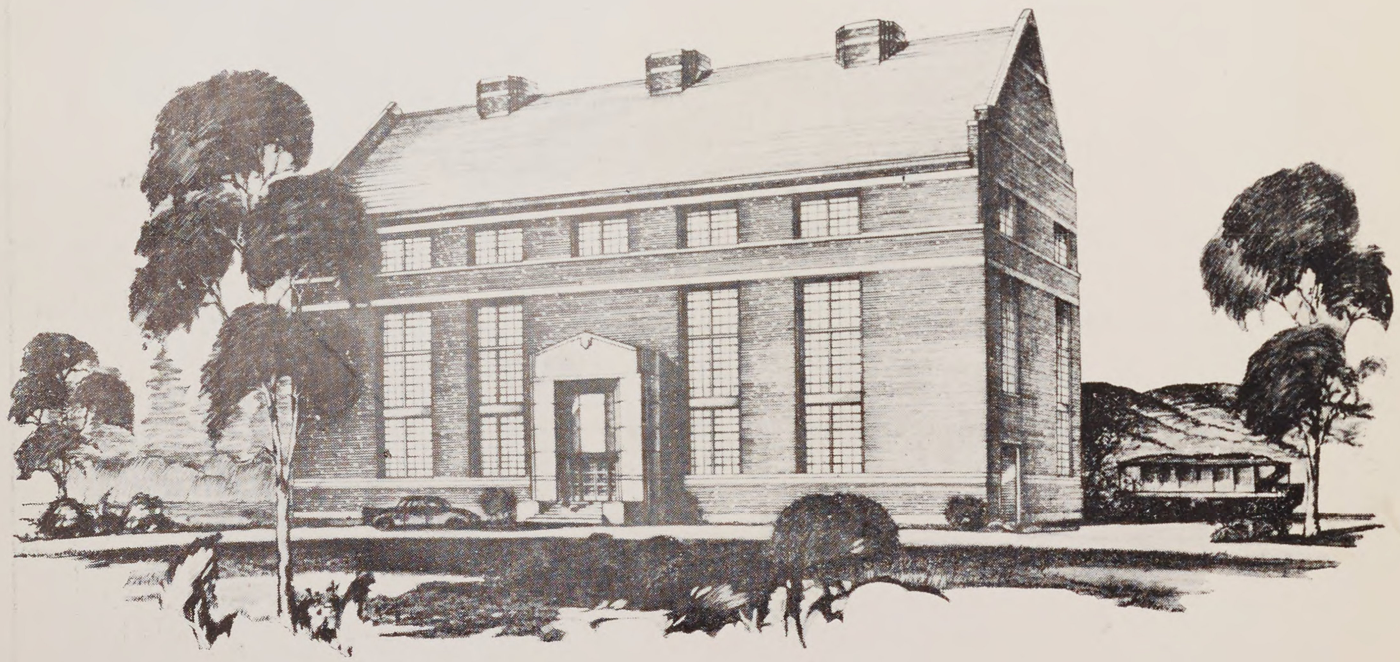
Michigan State College

STEAM GENERATING PLANT

South Campus



Department of Buildings and Utilities

MICHIGAN STATE COLLEGE

East Lansing

M.S.C. SOUTH CAMPUS POWER PLANT

CONSTRUCTED 1948

Welcome to Michigan State's new power plant. We, the power plant personnel hope your visit is a pleasant one and that you will be as proud of our plant as we are.

To help you on your tour of our power plant and to give you reference material for future use, this short discussion of our plant has been written.

Let us examine the reasons for the power plant expansion just completed. The necessities included a steam pressure of 100 p.s.i. (pounds of steam per square inch) for South Campus heating and other processes, such as heat for dormitory ovens, dairy and other college equipment requiring steam.

The North Campus power plant was already producing 150 p.s.i. which furnished a design pressure for two 500 kilowatt generators, also 150 p.s.i. providing a design pressure of 250 for a third 3,000 kilowatt generator with a single extraction of 15 p.s.i. used in heating. Due to the increased number of buildings on campus a demand for 6,000 kilowatts was expected. To meet such a demand a fourth generator was installed with a capacity to produce 3,000 kilowatts. This generator, because of its double extraction of 100 p.s.i. and 15 p.s.i., furnished the 100 p.s.i. used for South Campus heating and other processes. Two of the more important ones are mentioned above.

The decision to replace the old boilers with two new ones was made because the three boilers then in service were near retiring age. The two new boilers each producing 350 p.s.i. could be used to furnish pressure at 300 p.s.i. for byproduct electric power.

Our plant consists of two 1420-horse power, Wickes bent tube boilers; three drums, and other equipment producing 110,000 pounds of steam per hour at a temperature of 550 degrees F. at 315 p.s.i. steam pressure.

Each boiler, when operating at 110,000 pounds of steam per hour, burns coal at the rate of five to six tons per hour, depending upon the grade of coal used.

Listed below are a few facts and figures that may be of interest:

Boiler gross efficiency at 110,000 lbs. of steam per hour 84.5%

Pounds of coal burned per hour at 110,000 lbs. steam per hour .... 11,970 lbs.

Boiler heating surface .... 12,581 sq. ft.

Stoker grate area .... 234.4 sq. ft.

We sincerely hope you have enjoyed your visit through our plant and that some day you may visit us again.

We thank you very much,

Power Plant Personnel.

O-510

Asst. Custodian, part time (2)

Coal Handling, part time (1)

North Campus Power Plant. Note the South Campus Power Plant in the background.

PLANT EQUIPMENT

Two boilers	Wickes Boiler Co.
300 psi 110,000 lb. per hr. at 550°F. 12,531 sq. ft. heating surface 2144 sq. ft. water wall heating surface	
Two air heaters, tubular type	Wickes Boiler Co.
7200 sq. ft. heating surface	
Two superheaters, bare tube return bend	Foster Wheeler Corp.
Soot blowers	Diamond Power Specialty Corp.
Coal conveyors	Stephens Adamson Mfg. Co.
	Stock Engineering Co.
Coal spouts and coal scales	Stock Engineering Co.
Ash removal system	United Conveyor Co.
Dust collector, mechanical	Western Precipitation Co.
Continuous blowdown system	Permutit Co.
Blowdown valves, OS and Y; safety valves; non-return valves	
	Edward Valves Inc.
	Consolidated Valve Corp.
Water gages	Yarnall-Waring Co.
	Bailey Meter Co.
Water columns	Reliance Gauge Column Co.
Combustion control	Bailey Meter Co.
Flowmeters	Bailey Meter Co.
	Hays Corp.
Stokers, spreader type	Detroit Stoker Co.
4 feeders, motor driven	
Stoker drive, PIV	Link-Belt Co.
Cinder-reinjection system	Detroit Stoker Co.

Forced-draft fan, damper control	Clarage Fan Co.
F-D fan motor, 2 speed 75/27 H.P.	General Electric Co.
Induced-draft fan, vane control	Clarage Fan Co.
I-D fan motor, 2 speed 200/50 H.P.	General Electric Co.
Air compressor, Air King	Worthington
Air compressor R X 7	Gardner Denver
Boiler feed pump	
2,117 gpm motor drive	De Laval Steam Turbine Co.
Boiler feed pump motors (4)	General Electric Co.
Boiler feed pump, dual drive 234 gpm (1)	
Boiler feed turbine (1)	De Laval Steam Turbine Co.
Boiler feed pump, motor drive 234 gpm	
Underground piping	Ric-Wil Co.
General piping and fittings	Tube Turns Co. Inc.
	Midwest Piping and Supply Co.
Pipe Covering	Union Asbestos and Rubber Co.
Switch gear and switch board	General Electric Co.
Chemical feed pump	Hills McCanna Co.
Chemical injection system	Hagan Corp.
Water consultants	Hall Laboratories
Consulting Engineer	Claud R. Erickson

Part II

PLANT OPERATION

A plant is known by how it operates; that is, if it is a "getting-by plant" or a progressive plant.

Most machinery will run without much care, but such operating practices will be accompanied with low efficiencies, low reliabilities, and a large overhead. To engineer a plant requires trained personnel, correct operation procedures, keeping of records, checking of efficiencies, and continual effort to improve operation.

Objective: To operate the plant in an engineering manner thus at design efficiencies and as economically as possible, to meet all load demands and continue operation for long periods without forced outages. To improve operating conditions, always be on the alert for the unusual.

OPERATING PERSONNEL

It is the personnel which makes a plant. If the personnel are trained, reliable, and are proud of the plant in which they work, a large net saving will result.[2] Thus, boiler efficiency will increase, maintenance will decrease, and forced outages will be negligible.

Personnel Problems

This is a hard subject with which to deal, but is probably the most important if the plant is to operate in an efficient manner.

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2. David Moffat Myers, Reducing Industrial Power Cost, New York, McGraw-Hill Book Company, Inc., 1936, page 14.

Fig. 5

MICHIGAN STATE COLLEGE POWER PLANT

PLANT OPERATION DATA FOR TWO YEARS

ENDING WITH THE 1949-1950 FISCAL YEAR

	49-50	48-49
Average Temperature	46.3°F.	49°F.
Cooling Water Temp. Range	33°-59°F.	
Coal Consumed	53,283 Tons	49,879 Tons
Gross Steam Generated	985,317,182 lbs.	900,495,111 lbs.
#1 Boiler Generated	397,466,925	359,376,937
#2 Boiler Generated	324,460,000	397,206,375
#5 Boiler Generated	99,411,474	20,285,160
#6 Boiler Generated	163,978,783	118,541,603
#7 Boiler Generated	0	5,085,036
System Steam Peak	219,000 lbs.	195,000 lbs.
#1 Boiler Peak	122,000	115,000
#2 Boiler Peak	112,000	122,000
#5 Boiler Peak	49,000	37,000
#6 Boiler Peak	85,000	61,000
#7 Boiler Peak	0	50,000
Gross Electrical Gen.	30,542,500 kw	27,624,100 kw
#1 Turbine Gen.	175,500	279,300
#2 Turbine Gen.	799,000	1,115,800
#3 Turbine Gen.	13,609,000	15,103,000
#4 Turbine Gen.	15,959,000	11,126,000
System Electrical Peak	6,800 kw	6,300 kw
Total Electrical Used	27,669,500	24,461,000
% Increase Over Previous Yr.	12.5%	14.3%
Electricity Bought	376,000 kw	709,000 kw
Electricity Sold	3,249,000	2,872,000
Boiler Room Cu. Ft./kw	125	125
Turbine Room Cu. Ft./kw	20.3	20.3
Office Space Cu. Ft./kw	.985	.985
Coal Storage Tons/kw	3.57	3.57

Following are several steps that should be in practice in any power plant and which make for good labor relations:[3]

1. A supervision that is honest, understanding, and gives credit where credit is due.

2. Plant policies must be followed to the letter (no favorisms).

3. Talk with personnel about coming changes. Allow him to feel and be part of the organization.

4. Encourage a man to think. Listen to his ideas for they may be of great value.

5. Never be too busy to listen to a man. Always find and give him the most correct answers regardless of how long it takes.

6. Wages must be in line with other industries in the area.

Training Programs

The job cannot be made to fit the man. Therefore, the man must be trained to fit the job. Thus, training is an endless process.

Following are some methods that may be used in training personnel:[4]

1. Organized study courses.

2. A plant library.

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3. Norman J. Powell, "A Value System in Personnel Administration", Personnel Administration, Vol.7, (May 1945), page 14.

4. Alfred M. Cooper, Employee Training, New York, McGraw-Hill Company, Inc., 1942, pages 97-98.

3. On the job training.

4. Encouraging men to belong to national organizations.

5. Question-Answer sheets.

Organized Study Courses

At the present time two meetings per month are held on a voluntary basis, to discuss and answer all questions pertaining to plant operation, such as plant casualties, securing equipment, piping systems, and the theory of combustion.

It is the author's opinion that much would be gained by having these meetings compulsory. Pay should be given the men for attending and examinations given for qualifications of the various jobs. Thus, it is hoped in the near future that a set rate may be given to each man who attends.

A Plant Library

A bookcase has been provided on the operating floor in which to keep technical literature. It contains a copy of all machine instruction books, power and steam generating magazines, and various power hand books and bulletins.

On the Job Training

Various on the job training programs are underway. A few are as follows:

1. Interchanging firemen between plants.

2. Requirement that an assistant fireman learn the basic firing principles within a given length of time and qualify for firing within another certain date.

3. A man must fire for at least 6 months before becoming a repairman. This is very essential because many

repair jobs depend upon the knowledge of operation procedures.

4. Farming out men to various other departments during slack times to learn pipe fitting, welding, pipe covering, etc..

Encouraging Men to Belong to National Organizations

In the near future Lansing will have a chapter of the National Association of Power Engineers. Our men will be greatly encouraged to join this organization.

Question-Answer Sheets

Various question-answer sheets are cut out of magazines and posted on the bulletin board. Also, a question box is provided and at regular intervals a question-answer sheet is made up of these questions and posted on the bulletin board.

Labor Relations

The only prevailing problem is an excessive amount of labor turn over. This is a very serious problem and should be given careful inspection.

Following are the various reasons and remedies for excessive turn over:

1. Low Wages.
2. Advancements and Transfers.
3. Deaths and Retirements.

Low Wages (30% per year)

Low wages are the most common reason for labor turn over. This is the most expensive because it is the most progressive and most conscientious employees that leave for this reason. Consequentially, wages should correspond with wages in other

industries in that area.

Advancements and Transfers (14% peryear)

It is a healthy plant that can offer advancement and transfers. They should be e couraged for a happy man is a faithful employee. Training programs are a must to have trained men to fill vacancies.

Deaths and Retirements (7% per year)

Although this is the smallest of the group, it may be more costly because these are the men that have been with the plant for sometime. As stated above, a plant must carry a full scale training program to fulfill these vacancies.

OPERATION PROCEDURES

Organization calls for some method of procedures of confusion and waste is to be a minimum. These procedures should be as simple as possible, yet having various degrees of flexibility which depends upon each particular phase of operation. That is, you may write a guide for operation yet you cannot always give orders on how to handle each specific operation.

Operation Manual[5]

The operation manual is a reference book without which no well organized plant can do. It should be so constructed that new material, changes in procedures, and obsolete material may easily be removed or added. An obsolete manual is of no value and just makes for confusion.

Following is a construction guide in preparing the manual:

1. Be written at the lowest employees level.

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5. Personnel interview with Mr. Merle Newkirk, Power Division, The Dow Chemical Company, Midland, Michigan.

Fig. 6

Boiler Control Panel

2. Contain as much descriptive material, illustrations, and definitions as is necessary to make good comprehension of text.

3. Contain all plant policies, such as duties, care of equipment, general operation instructions, etc..

4. Explain as completely as possible what to do in extreme emergencies, such as low water, loss of fire, loss of boiler tubes, etc..

Lighting Off and Securing

Each fireman should be able to light off and secure all equipment in his charge. Consequentially, a definite procedure, which has been found most satisfactory, should be included in the operation manual and followed by all personnel.

As improper lighting off and securing may decrease the life of the equipment, proper explanations and training should be included in the plant training program.

Care of Equipment

The life of the equipment depends greatly upon the care that it has while it is in service. Most equipment outages may be traced back to faulty operational care either through carelessness, lack of experienced operators, or both. Therefore, both training programs and operation manuals are necessary.

They should contain procedures for regular checking of equipment, greasing and oiling charts, and the readiness of all standby equipment.

Operational Controls[6]

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6. Oliver Lyle, The Efficient Use of Steam, London, His Majestys' Stationery Office, 1947, pages 763-764.

For proper plant operation all operating personnel must understand the controls that they operate. This should include a fundamental knowledge of combustion, mechanics of controls, and proper care of the same.

If the plant objective is to be maintained, the manual must go into great detail and include illustrations to cover this material. Also, training programs should be included if waste is to be a minimum.

Standby Equipment

A definite procedure must be maintained for standby equipment. As this equipment may be needed on instant notice. This procedure should include oiling, turning machinery over, checking of alinement of valves, and the working of automatic equipment if provided.

Running Proper Equipment

Where two sizes of equipment are provided, definite procedures should be set up on the use of this equipment. The resulting savings of running proper size equipment is warranted.[7] In addition, care should be used in running other unnecessary equipment, such as coal elevators, pumps, underbunker conveyors, etc..

Loading of Boilers

Procedures should be set up for the correct loadings of boilers. This should contain such information as banking boil-

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7. Robert H. Fernald and George A. Orrok, Engineering of Power Plants, New York, McGraw-Hill Book Company, Inc., 1927, page 343.

ers, excessive loads, and partial outages.

Again it is the operation manual and training programs which should completely cover this subject if the ultimate objective is to be maintained.

Running Log

Some form of a running log should be kept on the operating desk. This book is to be used for day by day instructions, notices of faulty equipment, operational needs, logging of equipment outages, etc..

This log should be complete and signed by the proper men of every shift. After the books are completed, they should be stored in the operating desk, where they may be referred to by all personnel.

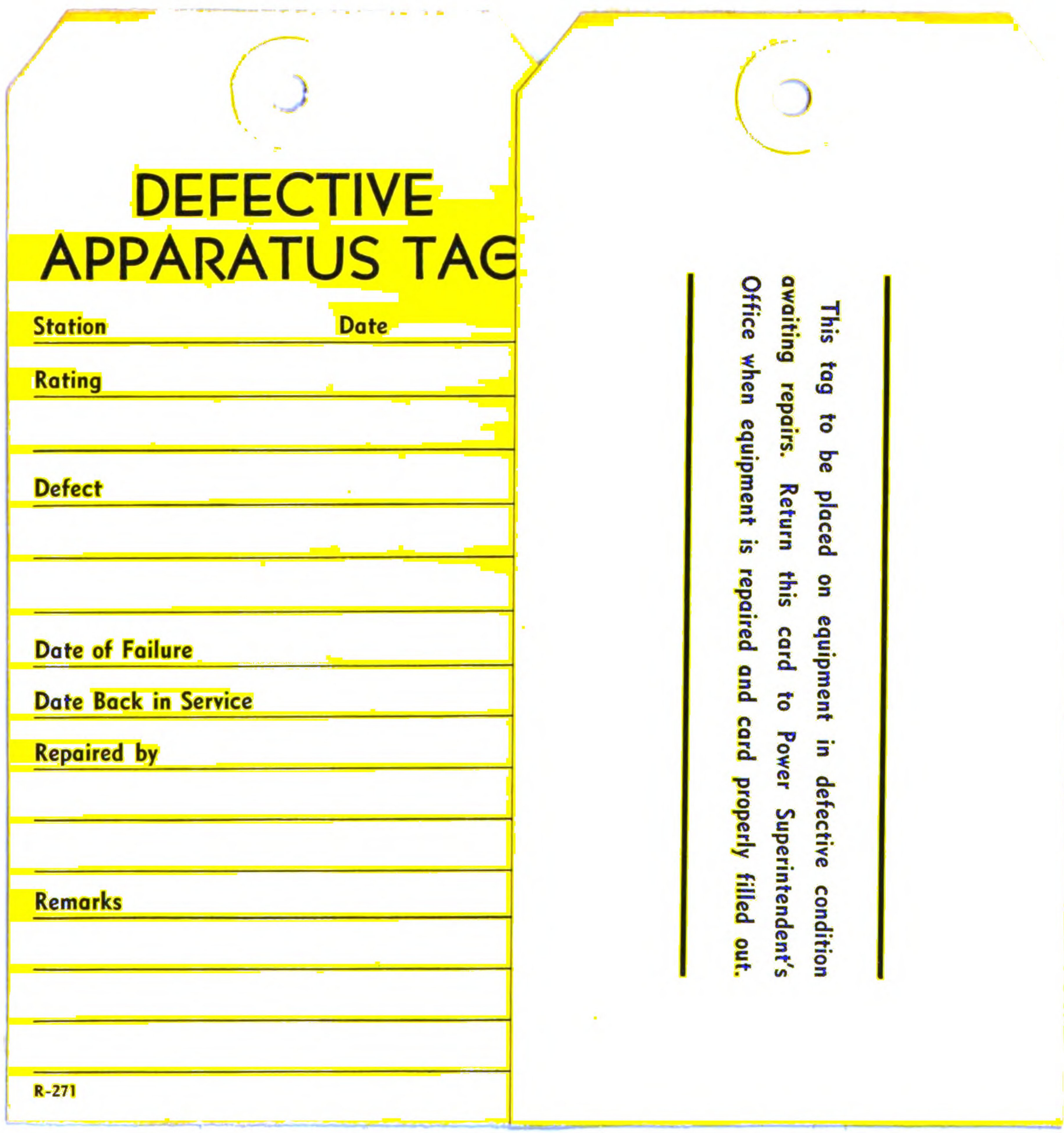
Alternating Equipment

Records should be kept on the running time of all equipment. From these records running time on duplicate machinery should be equalized as much as possible. The reasons for this are as follows:

1. To get maximum use of original investment.
2. To keep all machinery in good repair.

Operational Safety

To protect both men and equipment, when the latter is being repaired, definite safety procedures should be followed. These should contain proper methods of taging, throwing of switches, and logging of equipment out of service. The procedures should be compulsory for all personnel and disciplinary action should be warranted in case of failure to follow safety rules.



DEFECTIVE
APPARATUS TAG

Station Date

Rating

Defect

Date of Failure

Date Back in Service

Repaired by

Remarks

R-271

This tag to be placed on equipment in defective condition awaiting repairs. Return this card to Power Superintendent's Office when equipment is repaired and card properly filled out.

Fig. 7


WARNING
Station
Date
Unit
Check Following Items Before Starting
1
2
3
4
5
6
7
8
9
10
11
12
Tag Put On by
Tag Removed by
A. M.
P. M.
Date
R-269
E
EQUIPMENT
Name of Station
Equipment out of Service
Authorized by
Time Tagged
A. M.
P. M.
Date
Tagged by
Name of man who is to work on equipment
Describe work to be done
Removal will be ordered by
Authorized by
Ordered removed by
Removed by
Time tag was removed
A. M.
P. M.
Date
R-270

Fig. 8

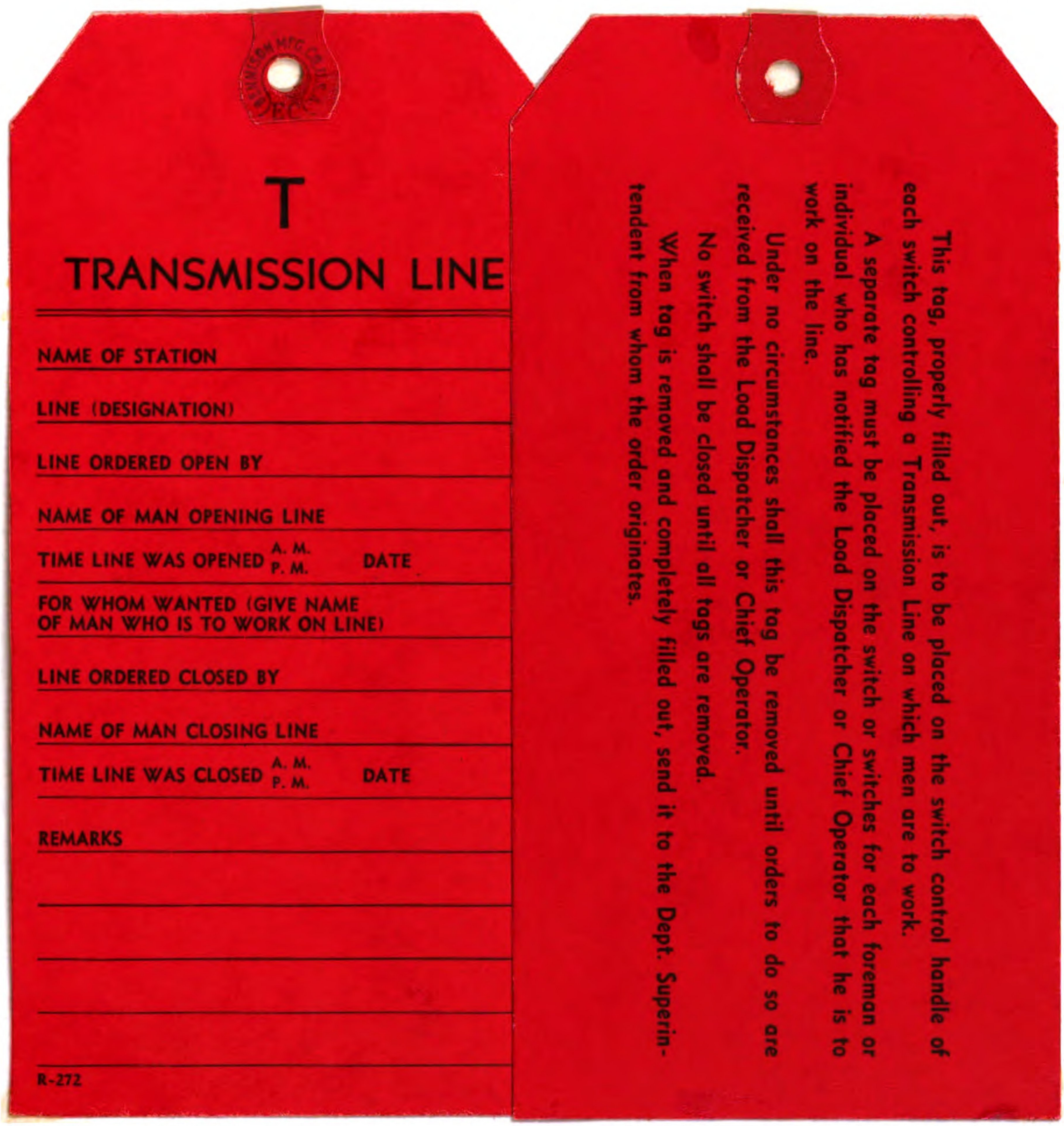

T
TRANSMISSION LINE
NAME OF STATION
LINE (DESIGNATION)
LINE ORDERED OPEN BY
NAME OF MAN OPENING LINE
TIME LINE WAS OPENED A. M. P. M. DATE
FOR WHOM WANTED (GIVE NAME OF MAN WHO IS TO WORK ON LINE)
LINE ORDERED CLOSED BY
NAME OF MAN CLOSING LINE
TIME LINE WAS CLOSED A. M. P. M. DATE
REMARKS
R-272
This tag, properly filled out, is to be placed on the switch control handle of each switch controlling a Transmission Line on which men are to work.
A separate tag must be placed on the switch or switches for each foreman or individual who has notified the Load Dispatcher or Chief Operator that he is to work on the line.
Under no circumstonces shall this tag be removed until orders to do so are received from the Load Dispatcher or Chief Operator.
No switch shall be closed until all tags are removed.
When tag is removed and completely filled out, send it to the Dept. Superintendent from whom the order originates.

Fig. 9

Following are examples of tags and taging[8] rules used in this plant:

Safety rules are an attempt by the management to control unsafe practices. This is not a sole function by the management and all men are requested and encouraged to make suggestions for new or modified safety rules.

The violation of safety rules is a serious offense and will result in lay-off or dismissal. Many rules are made to be broken intelligently. Not so with safety rules-it is seldom intelligent to break safety rules.

TAGGING RULES

1. Three types of safety tags are provided for general use. They are the yellow "defective apparatus" tag (Fig. 7, page 27), the green "warning" tag (Fig. 8, page 28), and the red "E" or "T" tag (Fig. 9, page 29). The yellow tag is filled out and placed on any piece of apparatus which is out of order or which does not function properly. It may be either in or out of service. The green warning tag is filled out and placed on any apparatus which requires special precautions in operation or handling in order to protect the equipment from damage. The red "E" or "T" tags are filled out and placed wherever operation would endanger the workmen. The "T" or Transmission line tags are used on

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8. The tags and tagging rules information was received from Mr. William Butler, Chief Power Plant Engineer, Dow Chemical Co., Ludington, Michigan.

the switchboard only. The "E" or Equipment tags are used on all other equipment.

2. No red tag is ever to be removed or the equipment operated which is under the protection of a red tag without authorized permission from the person so designated on the tag.

3. No valve or switch is ever to be operated with a red tag in place. The proper man must first remove it.

4. All tags must be obtained from the foreman. All red tags are numbered and a record of their locations is kept by the fireman. No red tags may be placed except by permission from the supervisor. No maintenance work may be started without first obtaining written clearance from the supervisor. The red tag properly filled out and placed constitutes this written clearance.

5. Any red tag may be removed after working hours only by a superior to the man who placed it after a careful investigation has been made.

6. The responsibility of seeing that tags are properly placed to protect maintenance crews rests solely with the fireman. Maintenance men should assure themselves that they are properly protected before starting work.

LOCKS & CHAINS

It should be born in mind that in some dark locations a red tag is little or no protection because it may not be readily seen. Locks and chains are sometimes used in such locations.

Problems

Operation procedure problems are as follows:

1. Trained personnel.
2. Changing of procedures.
3. Sacrificing economy for reliability.

Trained Personnel[9]

As economy and reliability of the plant rest with the experience of the operating personnel, it is very important that these men are highly trained. With trained men desirable procedures become a habit, thus, reliability and economy increase. Therefore, training programs and correct wages are very essential in the well organized plant.

Changing of Procedures

From time to time it becomes necessary to change operational procedures. This may be due to new and better methods or replacing of obsolete equipment. Consequentially, operation manuals and training must be kept up to date to avoid resulting confusion.

Sacrificing Economy for Reliability

There are times that it is very difficult to decide which has preference over the other, economy or reliability. This is a supervision problem and can only be answered by knowing the existing condition of equipment and the lapse of time that standby equipment may be put into service.

To solve such problems it is well to weigh the cost of running extra equipment against the value of reliability. Follow-

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9. David Moffat Myers, Reducing Industrial Power Cost, New York, McGraw-Hill Book Company, Inc., 1936, page 16.

ing are a few suggestions in solving this problem:

1. Keeping records of running time of equipment between outages.

2. Keeping records of known maintenance work to be done on equipment when it is out of service.

3. Practice preventive maintenance.

OPERATING CONDITIONS

Due to varying weather conditions, working and school hours, and human habits, steam demand is a variable. This demand varies from day to day and season to season as the accompanying graphs and charts show. Therefore, it is well to discuss summer and winter operations.

<u>Winter Operation</u>

Winter operation is considered the period when classes begin in late September till the beginning of June. This is the period when heating processing and electric loads are the maximum as shown in the accompanying graphs (Figs. 10 and 11, pages 34 and 35).

<u>Boiler Loads</u>

With the opening of school in late September throughout October week day peak loads of 150,000 lbs. steam per hour may be expected. These peaks are usually for periods of about 6 hours during the day. On Saturdays the peak load is about 130,000 while the Sunday peak is only about 110,000.

Consequentially, during the week two boilers are operated. While on Friday night one boiler may be secured and lit off again on Monday morning. This means that for a period of a few hours on Saturday some electrical power will have to be pur-

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Fig. 10

GRAPH OF STEAM AND ELECTRICAL LOAD CURVE FOR FISCAL YEAR 1948-1949

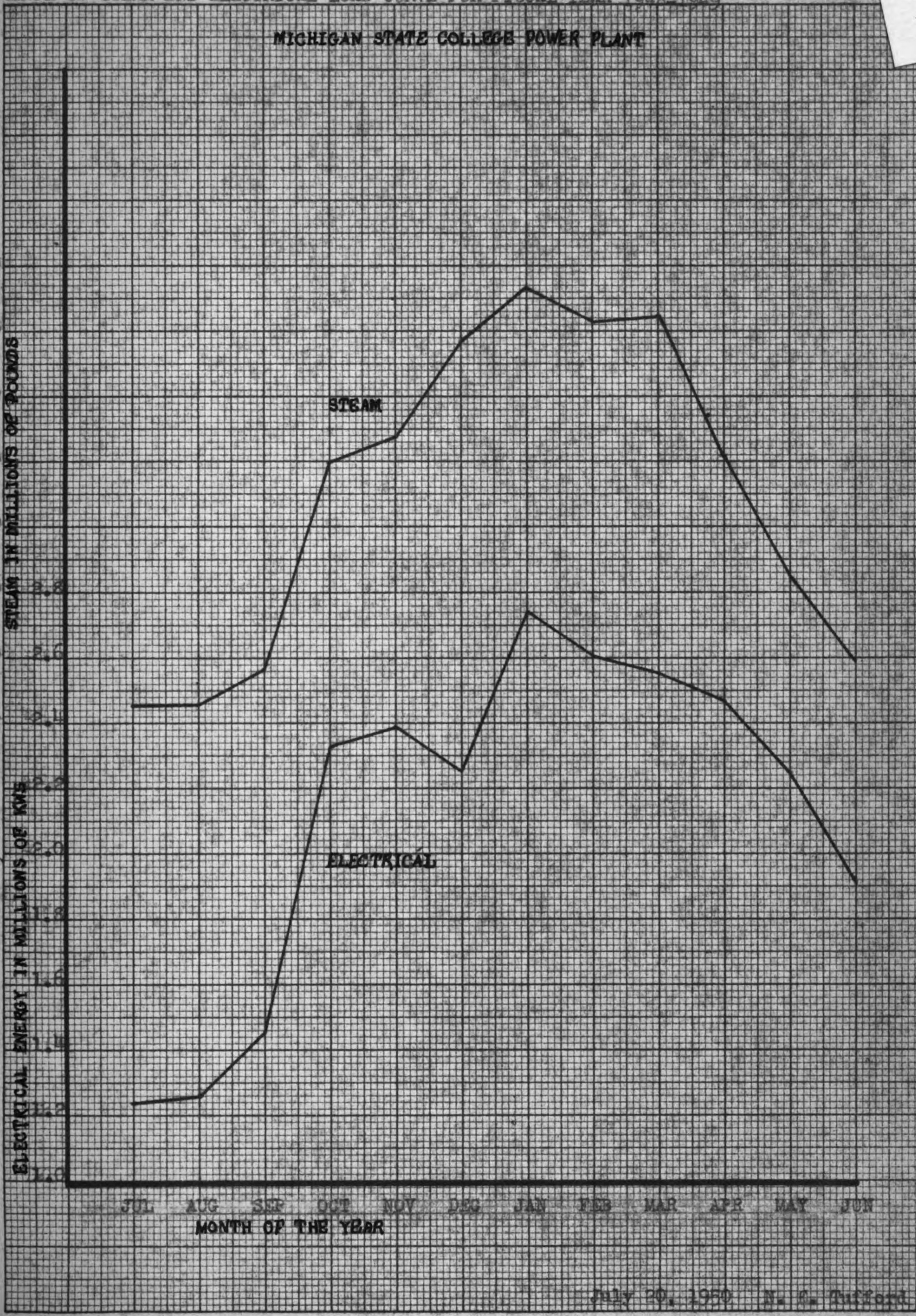
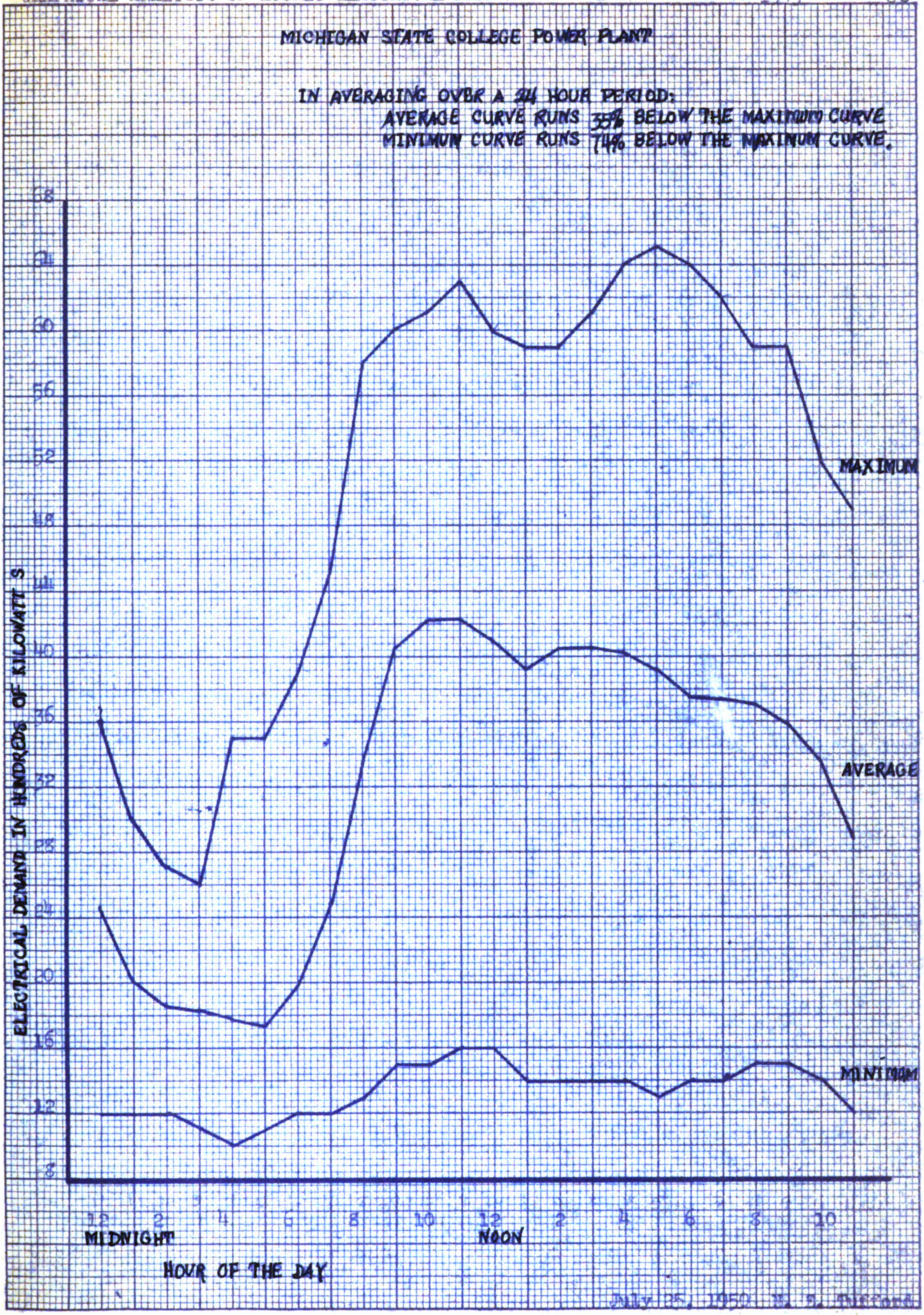


Fig. 11

GRAPHICAL ANALYSIS OF HOURLY ELECTRICAL DEMAND FOR CALENDAR YEAR OF 1949



chased to keep the boiler within its operating limit.

However, the electrical tie-in with the city of Lansing is only rated at 2500 kw. Thus, when the electrical load is beyond the safe operating capacity of one boiler, both boilers will have to operate over the week-ends. This is also true when the heating load is too high to be supplied by turbine extraction for a given electrical load.

With the coming of November, week day boiler loads may be expected of 190,000 lbs. per hour and week-end loads of 140,000. So, two boilers must be operated continuously.

From the first of December until the last of March, peak loads of 220,000 lbs. per hour or more may be expected. It is a system policy to operate both plants for economy and reliability. The north campus plant is to furnish steam for the small turbines and the 100 lb. heating and process system while the south campus plant furnishes steam for the large turbines and their accompanying 100 lb. and 5 lb. extractions.

During Christmas vacation (a period of 3 weeks) the steam peak will decrease to about 160,000 lbs. per hour. Therefore, one boiler in each plant may be operated. Each boiler may have a week of outage for necessary boiler repairs at this time.

Then, in March between school terms (another two weeks) loads peaks of 150,000 lbs. per hour or lower may be utilized for boiler repairs.

From the period of April through May load peaks decrease. Therefore, the south campus plant operates two boilers while the north campus plant is secured.

<u>Reliability</u>

The operating objective is the production of steam for heating while electrical power is a by-product. The reason for this is that electrical power may be purchased while heating steam is unavailable on the market. Therefore, winter production must be adequate and reliable at all times to meet this heating demand.

To insure reliability, economy may have to be sacrificed. This may be explained by referring to the monthly load sheet for February (Fig. 12, page 38). From this sheet the highest south campus peak load was 170,000 lbs. per hour, the lowest 132,000, while the average load was 165,000. The north campus plant average load was 40,000 and the system peak was 219,000.

The south campus plant could possibly have handled the entire load at all times throughout the month. Since, this would have been maximum load on each boiler leaving no leeway in case of partial outages, to insure a continuous steam supply to all consumers an additional boiler was operated and economy was sacrificed for reliability.

Reliability problems are as follows:

1. Trained personnel.
2. Electrically operated auxiliaries.
3. Dependency on north campus plant.
4. One source of electrical power.
5. No auxiliary lighting circuit.
6. Need of larger electrical tie-in.
7. Dependable coal system.

The first item was covered under personnel. The next three items are all related. They may be explained as follows.

MONTHLY LOAD SHEET

Month of FEBRUARY

Fig. 12

DAY	COAL	LOAD IN THOUSAND LBS/HR					STEAM LOAD/DAY		EVAP	F W
	TONS/DAY	AVER	MIN	TIME	MAX	TIME	INTEGRATOR	ACTUAL	RATE	TEMP
1	158	125	105	3 AM	148	9 PM	2490	3110000	8.5	184
2	176	137	91	4 AM	164	2 PM	2617	3280000	9.3	177
3	176	140	104	11 PM	157	9 AM	2592	3240000	9.2	180
4	160	132	109	2 PM	142	7 AM	2361	2957250	9.2	187
5	132	115	100	12 M	120	12 N	2175	2720000	8.9	190
6	175.5	130	96	1 AM	155	10 AM	2510	3140000	9.1	185
7	174	135	104	2 AM	157	9 AM	2534	3170000	9.1	182
8	177	138	107	2 AM	157	9A M	2653	3310000	9.35	182
9	185.7	140	108	3 AM	160	4 PM	2574	3220000	8.7	187
10	174.5	130	97	11 PM	154	12 N	2461	3080000	8.8	188
11	152.4	112	58	3 AM	132	12 AM	2126	2660000	8.8	186
12	161.0	115	95	1 AM	133	9 AM	2200	2750000	8.55	190
13	184.8	141	99	12 M	161	2 PM	2605	3280000	8.85	186
14	181.0	135	90	3 AM	155	3 PM	2478	3100000	8.57	165
15	184.9	148	98	3 AM	160	11 AM	2541	3180000	8.60	186
16	189.1	135	102	2 AM	154	9 AM	2499	3120000	8.27	186
17	167.5	129	94	2 AM	144	11 AM	2332	2910000	8.7	182
18	157.7	115	96	4 AM	125	10 AM	2077	2600000	8.24	187
19	151.3	111	95	2 AM	128	10 PM	2087	2610000	8.37	190
20	166.8	132	110	2 AM	170	9 AM	2548	3190000	9.[illegible]	186
21	187.2	144	109	3 AM	150	10 AM	2405	3000000	8.05	186
22	182.7	140	101	11 PM	146	10 AM	2328	2910000	8.00	186
23	167.0	130	90	2 AM	138	4 PM	2235	2800000	8.37	
24	140.7	125	84	2 AM	138	10 AM	2252	2810000	8.2	188
25	161.7	127	93	2 AM	147	10 AM	2058	2560000	7.92	186
26	152.2	105	84	5 PM	127	10 AM	1965	2560000	8.1	188
27	161.1	110	83	12 M	138	8 AM	2100	2630000	8.15	188
28	152.1	100	77	3 AM	127	11 AM	1980	2480000	8.15	190

With loss of the electric circuit which feed the plant or the complete loss of all campus circuits the plant is automatically secured because all auxiliaries except one boiler feed water pump are electrically driven.

Also, if the north campus house circuit fails, the plant is without a source of feed water since all water pumps (both feed water booster and raw water) are in the north campus plant. The only south campus feed water reserve is a 50,000 lb. storage tank which is a half hour supply at the most.

It must also be kept in mind that while the turbines may be out of service the heating load is still in demand. This may cause a serious condition as this demand for heating steam may draw the boiler pressures down to the danger point before electrical supply is resumed.

It is recommended that a non-condensing house turbogenerator be installed in the south campus plant to remedy this condition. Another possible solution could be an electrical tie-in with the Consumers Power Company.

At the same time a raw water pump should be installed from the new reservoir on our electric circuit for use as an emergency feed water supply.

As for item number 5, at the present time there is no auxiliary lighting circuit. The author feels that if plant casualties in darkness are to be handled in minimum time it is necessary to install this lighting system immediately.

Item number 6 (Need of larger electrical tie-in) is very important. Not only will it increase plant reliability but will increase plant economy by being able to buy when load peaks of short duration means two-boiler operation.

Also, when the plant is operating two boilers at near peak load and a partial outage takes place due to stoker troubles a larger tie-in would handle the electrical load thus releasing this steam for heating until necessary stoker repairs are made.

The last item is covered under coal (page 53) and may be referred to under that heading.

Summer Operation

Summer operation covers the period from the first of June until school starts late in September. This is the period when heating, processing, and electrical loads are a minimum. Therefore, during this period all large scale plant maintenance should be accomplished.

Summer Loads

The highest loads during this period may be expected the first two weeks in June. By referring to Fig. 13, page 41, it may be seen that a week day peak of 113,000 lbs. per hour was obtained. While during the later part of the month daily peak loads were only 94,000, while daily average peaks were 75,000 and the minimum peaks were 68,000. This is comparable to daily loads during July and August.

This calls for one-boiler operation. Therefore, summer maintenance is completed on the secured boiler, then the boilers are reversed and the other boilers' maintenance is completed.

From the first of September until school starts, when campus activities are the least, the steam peak is 75,000 lbs.

MONTHLY LOAD SHEET

Month of June

Fig. 13

DAY	COAL	LOAD IN THOUSANDS LBS/HR					STEAM LOAD/ DAY		EVAP RATE	F. W. TEMP
	TONS/ DAY	AVER	MIN	TIME	MAX	TIME	INTEGRATOR	ACTUAL		
1	111.6	90	60	3 AM	106	2 AM	1636	2042400	9	224
2	115.2	80	62	4 AM	110	9 AM	1688	2110000	9	225
3	109.1	80	60	2 PM	99	11 AM	1498	1872500	9	222
4	94.6	75	65	2 AM	84	4 PM	1437	1796250	9.4	219
5	106.5	79	61	5 AM	102	10 AM	1603	2003750	9.4	218
6	102.5	82	58	2 AM	101	12 N	1591	1989750	9.7	221
7	97.7	80	60	6 AM	100	5 PM	1585	1960000	9.8	221
8	102.4	82	62	5 PM	100	4 AM	1603	2030000	9.9	223
9	102.1	81	60	5 AM	101	3 PM	1509	1960000	9.6	216
10	87.9	74	58	3 AM	86	10 AM	1378	1720000	9.5	216
11	80.6	70	55	3 AM	75	12 N	1250	1560000	9.7	216
12	101.1	73	57	2 AM	100	11 AM	1497	1870000	9.2	218
13	101.1	81	51	2 AM	103	11 AM	1515	1890000	9.3	220
14	89	77	60	12 M	90	12 N	1355	1700000	9.8	220
15	86.3	76	56	1 AM	89	12 N	1329	1660000	9.65	219
16	87.5	76	56	3 AM	88	3 PM	1532	1680000	9.6	218
17	80.8	70	55	1 AM	79	9 AM	1227	1530000	9.5	217
18	76.8	69	54	3 AM	75	10 AM	1200	1500000	9.6	214
19	93.2	75	54	5 AM	92	9 AM	1437	1796250	9.6	216
20	92.7	74	58	12 M	92	10 AM	1414	1767500	9.[illegible]	220
21	87.8	72	54	3 AM	90	11 AM	1387	1740000	10.5	220
22	88.5	75	53	3 AM	92	10 AM	1381	172900	9.7	219
23	83.5	74	53	3 AM	91	10 AM	1264	1585000	9.5	220
24	76.5	67	50	6 AM	72	10 AM	1106	1381000	9	220
25	68.9	65	52	2 AM	66	12 N	1134	1419000	10	219
26	89.2	74	70	7 PM	92	10 AM	1377	1721000	9.6	219
27	96.2	77	52	3 AM	93	12N	1390	1738000	9	225
28	97.5	75	53	3 AM	88	2 AM	1400	1740000	8.9	227
29	97.7	76	52	4 AM	90	12 N	1376	1720000	8.8	224
30	97.0	77	52	1 AM	94	11 AM	1380	1725000	8.9	227

per hour. The electrical peak loads are 3500 kw.

During this period the south campus plant is secured for plant maintenance which cannot be completed when a boiler is on the line. Consequentially, two boilers must be operated in the north campus plant to meet the necessary steam demand.

<u>Reliability</u>

During summer operation the steam demand peaks for heating and processing range from 25,000 to 35,000 lbs. per hour, while maximum electrical demand is 4800 kw. Thus, for partial boiler outages electrical power must be purchased.

Summer reliability is somewhat sacrificed for economy to complete necessary plant maintenance. Also, the possibility of outages is greatly reduced by decreased loads and well maintained boilers.

<u>Problems</u>

Besides the problems listed under reliability the following operational problems exist.

1. During summer operation the steam extraction load is very small compared to the existing electrical load. Also, during extremely dry periods condenser cooling water not being available in sufficient quantities and at temperatures under 80°F. is a problem. Consequentially, to meet the electrical demand peaks either electrical power must be purchased or steam must be vented to the atmosphere.

2. In winter operation steam extractions from turbines, while running only south campus plant, may not be sufficient for existing heating loads, Therefore, there are times when a reducing station (from 300 to 100 psi) and the desuperheater must

be used.

The first problem is being investigated in a thesis by Michael Delich and Douglas Lee, whose problem is to determine if it would be practical to operate during the summer season with Diesel generators and a small package boiler for steam generation. If this solution should prove feasible besides solving the summer operational problem, it would make it possible to overhaul the complete plant each summer.

Also, another aid to better summer operation, if the college continues to expand, is to investigate the possibilities of evaporator condensers for future generators.

A possible solution for the second problem is the addition of either a 7500 kw or 5000 kw turbogenerator with double extraction. This machine would reduce the present necessary use of the reduction station considerably.

OPERATION RECORDS[10]

Records are a continuous history of the plant. Therefore, the records should be adequate and complete. They are used for reference, determining future demands, need of boiler maintenance, boiler control, plant efficiencies, etc..

Needs of Records

So great is the amount of information needed to properly operate a power plant that no one group of persons can quickly produce the necessary information from memory, thus, records are necessary. Some records are required by law, others by in-

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10. Frederick T. Morse, Power Plant Engineering and Design, New York, D. Van Nostrand Co., Inc., 1942, page 672.

surance companies, while still others are needed to obtain plant production information.

Following is a list of various needs for records:

1. To maintain proper boiler control.
2. To plot various data sheets such as daily peaks, monthly peaks, service time, etc..
3. To practice preventive maintenance.
4. To determine future load trends.
5. Value of trained personnel.
6. Future need for equipment and possible plant expansion.

Types of Records

Some of the various types of records used are as follows:

1. Metering charts, such as steam-air flow, flue gas temperatures, CO_2, steam pressure, etc..
2. Daily, weekly, monthly, etc., production control records. See Figs. 14 and 15, pages 45 and 46.
3. Efficiency test data records. See Fig. 16, page 47.
4. Machinery running time records.

Evaluating Records

Records should not be made and then just filed away for future reference. They should be studied very carefully for ways and means of increasing plant reliability, economy, and efficiency.

Below is a list of several items that may be used as a guide in evaluating records:

1. Checking flue gas temperatures charts for indications of leaky baffles.

MICHIGAN STATE COLLEGE POWER PLANT
PLANT REPORT

MONTHLY LOG

YEAR 1950
MONTH July

DAY	TOTAL LBS OF COAL	LBS OF WATER EVAPORATED	EVAP/LB OF COAL	GALLONS OF MAKEUP WATER	% MAKEUP TO TOTAL	LBS OF STEAM TO TURBINES	KWH GENER	LBS STEAM/KWH	AV TEMP
1	164,000	1,503,750	9.16	22,000	12 20	1,503,750	54,000	28.8	60.9
2	152,000	1,388,750	9.13	31,400	18 85	1,388,750	47,000	29.5	64.7
3	175,800	1,595,000	9.07	29,800	15 58	1,595,000	62,000	25.7	61.6
4	154,600	1,598,750	9.04	28,400	16 93	1,398,750	48,000	29.1	70.1
5	190,400	1,695,000	8.90	29,100	14 31	1,695,000	69,000	24.6	63.6
6	190,000	1,702,500	8.96	30,000	14 69	1,702,500	68,000	24.7	63.1
7	189,000	1,710,000	9.04	30,100	14 68	1,710,000	71,000	25.0	58.0
8	163,200	1,511,250	9.26	30,000	16 55	1,511,250	55,000	27.7	70.5
9	153,600	1,400,000	9.11	27,100	16 14	1,400,000	48,000	29.2	72.2
10	191,600	1,748,750	9.12	33,100	15 78	1,748,750	71,000	24.7	73.4
11	190,000	1,741,250	9.16	37,300	18 10	1,741,250	72,000	24.3	75.3
12	194,000	1,752,500	9.03	29,200	12 89	1,752,500	72,000	24.3	77.2
13	204,400	1,783,750	8.72	31,000	14 49	1,783,750	75,000	23.8	63.4
14	193,800	1,711,250	8.82	29,700	14 47	1,711,250	69,000	24.8	61.9
15	163,200	1,488,750	9.12	27,300	15 57	1,488,750	51,000	29.1	68.3
16	155,400	1,396,240	8.98	29,800	17 70	1,396,250	65,000	21.7	73.4
17	196,000	1,737,500	8.86	31,100	14 93	1,737,500	69,000	25.1	71.0
18	196,000	1,768,750	9.02	30,300	14 28	1,768,750	72,000	24.6	66.1
19	195,200	1692,500	9.18	37,100	17 26	1,792,500	75,000	23.9	62.2
20	198,200	1,778,750	8.97	32,200	15 09	1,778,750	75,000	23.6	56.1
21	186,400	1,681,250	9.01	34,300	17 01	1,681,250	68,000	24.7	65.3
22	162,400	1,478,750	9.10	33,500	18 89	1,478,750	54,000	27.5	64.4
23	149,200	1,405,000	9.41	27,900	16,56	1,405,000	62,000	22.7	71.3
24	184,600	1,693,750	9.17	31,200	15 36	1,693,750	102,000	16.8	67.3
25	183,800	1,683,750	9.16	30,000	14 85	1,683,750	68,000	24.8	66.4
26	172,800	1,680,000	9.72	30,800	15 29	1,680,000	69,000	24.4	69.7
27	187,600	1,690,000	9.00	40,100	14 78	1,690,000	67,000	25.2	63.8
28	180,000	1,685,000	9.36	31,600	15 64	1,6850000	69,000	24.3	73.5
29	156,200	1,495,000	9.57	32,400	18 07	1,495,000	56,000	26.7	74.9
30	146,000	1,368,750	9.37	30,500	18 58	1,363,750	46,000	29.7	74.0
31	186,600	1,701,250	9.11	46,600	22 84	1,701,250	67,000	25.4	70.2
TOT.	5,506,000	50,167,500		975,900		50,167,500	1,945,000		
AVG.	177,612	1,618,306	9.11		14 78	1,618,306			68.0

Fig. 14

POWER PLANT

DAILY OPERATING SHEET
SUMMARY

DATE: 6/29/50

COAL ____97.____ TONS
____195,400____ LBS

STEAM ____1,720,000____ LBS

EVAP.RATE ____8.80____

AVER.OUTSIDE

TEMP. ____60.7____ DEG. F

MAKEUP ____15.41____ %
____265,212____ LBS

ELECT.LOAD

MAX. ____4000____ K.W.

MIN. ____2400____ K.W.

STEAM LOAD
MAX. ____90,000____ LBS/HR

MIN. ____52,000____ LBS/HR

(6360)

Fig. 15

Fig. 16

MICHIGAN STATE COLLEGE
BOILER METER AIR FLOW ADJUSTMENT DATA SHEET

BOILER NO. 2 METER TYPE ORSAT- HAYES CLASS ______ NO. ______ ENGINEER WOOLMAN DATE 8-8-50

TIME	STEAM FLOW	AIR FLOW	HEADER PRESS.	STEAM PRESS.	STEAM TEMP.	WATER LEVEL	CO_2	CO_2 Plus O_2	CO_2 + ~~O_2+CO~~	~~O_2~~	Total Air	FEED H_2O Press.	F. W. TEMP.	FLUE GAS TEMP.	AIR HTR. IN.	WIND BOX PRESS.	FURNACE DRAFT	UPTAKE DRAFT	AIR HTR. OUT	DUST COLL. OUT	I.D.	STOKER	F.D.
AM																							
9:00	72	72	300	312	542	0+.5	12.2	18.0	10.5	5.8	138	360	226	545	2.2	1.2	.08	.7	1.1	2.5	17	14	17
9:15	72	71	300	313	542	0+.1	11.4	18.8	10.5	7.4	153	360	226	545	2.2	1.2	.08	.7	1.1	2.6	17	15	16
9:30	72	72	300	315	541	0	11.8	18.2	10.5	6.4	143	355	225	545	2.2	1.2	.08	.7	1.1	2.6	17.5	14	17
9:45	71	72	300	315	541	0+.2	10.8	18.2	10.6	7.4	153	350	226	545	2.2	1.2	.08	.7	1.1	2.5	17.5	14	17
10:00	71	72	300	312	541	0+.3	11.8	18.4	11.0	6.6	144	355	225	550	2.2	1.2	.08	.7	1.2	2.6	17.5	14	17
10:15	61	61	300	310	540	+2	11.0	18.8	11.5	7.8	157	375	225	540	1.8	0.8	.08	.6	.9	2.0	16	14	16.5
10:30	60	60	300	310	540	0+.2½	11.4	19.6	10.5	8.2	162	385	226	530	1.8	0.8	.08	.6	.9	2.0	16	14	16
10:45	63	62	300	310	540	0+1	11.8	18.6	10.5	6.8	147	375	224	530	1.8	0.8	.08	.6	1	2.2	16	14.5	15
11:00	63	63	300	310	539	0+1.5	11.4	20.0	10.5	8.6	166	380	225	530	1.8	0.8	.1	.6	1	2	16	13.5	14.5
11:15	60	60	300	310	535	0+1	11.6	20.0	10.5	8.4	164	380	224	530	1.8	0.8	.08	.6	1	2.1	16.5	13	15
AVE.	72	72	300	313	541	+1.5	11.6		10.5	6.7	146	355	225	545	2.2	1.2	.08	.7	1.1	2.6			
AVE.	62	62	300	310	540	+1.5	11.4		10.5	7.9	159	375	225	530	1.8	.8	.08	.6	1	2.0			

FUEL BED 3-4 IN. NO CLINKERS
CLEAR STACK

2. Checking log sheets for faulty operation.

3. Checking log sheets, charts, or other data for faulty equipment.

4. Studying records for ways and means of increasing plant reliability, economy, and efficiency.

Problems

After very thorough examination of operation records the following problems are evident:

1. Need of qualified personnel.

2. Keeping records up to date.

3. Need of new record forms.

At the present time a receptionist who is not trained handles the processing of records. This is a fill-in job, therefore, records cannot be kept up to date or evaluated and processed correctly.

Thus, if a full time qualified person was assigned this job a net savings from increased plant efficiency and economy might more than pay his wages as explained under the evaluation of records.

COAL

The proper fuel, fuel handling, testing, and storage are the lifeline of the plant. Therefore, a considable amount of expense and time are spent in the proper handling of coal.

Following is a coal analysis which was taken from the boiler efficiency guarantee:

Moisture	3.6%
Volatile Matter	34.0%
Fixed Carbon	55.4%
Ash	7.0%

Sulphur 1.5%
BTU per lb. as fixed 13,500
Ash Fusion Temperature 2,500°F.

Coal Handling

The coal is dumped into a hopper outside the building either directly from the coal cars or by crane from the stock pile. From here it is fed to the coal crusher where it is ground to a maximum size of 1 inch. Also, a crusher by-pass has been provided for coals of 1½ inch top size or under.

A Redler conveyor system then lifts the coal from the crusher to overbunker conveyor which distributes the coal to the various bunkers, having a total capacity of 750 tons. Coal then may be drawn from any of the bunkers that are not directly above scales and fed to either boiler by the use of a Stock Engineering underbunker conveyor directly to the coal scale. See Fig. 17, page 50.

The coal is then directed to various stoker feeder hoppers through a Stock Engineering non-segregating coal spout, whose capacity is 3 ton of coal which is about a half hours supply after the coal failure alarm rings.

Coal Stock Piling

Past experience has shown that a stock pile of 30,000 tons of coal should be maintained through the winter months. This pile is built up during the summer for coal emergencies during the heating season.

The building of this stock pile[11] is done in the follow-

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11. Interview with Mr. Frank J. Lake, Coal Engineer of the Ohio Coal Association; concerning correct method of stock piling coal.

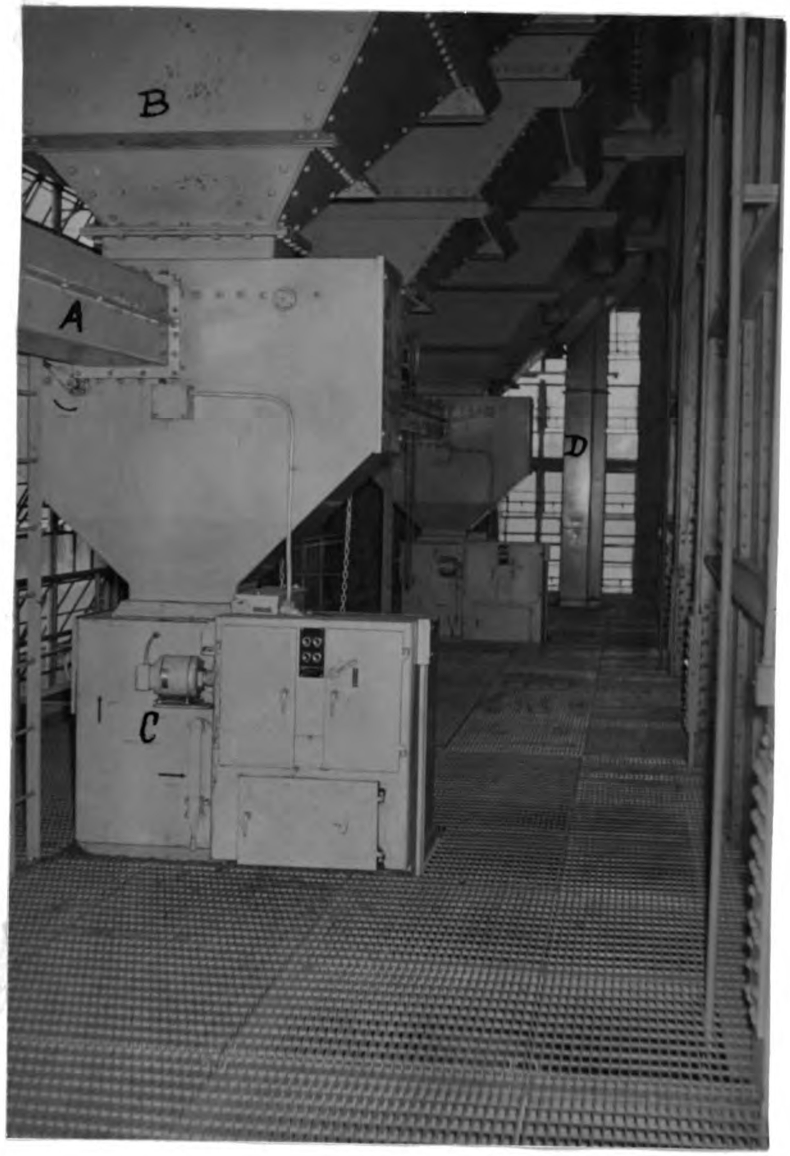

Fig. 17

Coal scale floor showing: A-underbunker conveyor, B-coal bunkers, C-coal scale, and D-coal elevator.

Fig. 18

Constructing the 30,000 ton stock pile. At present time stock pile contains about 10,000 tons.

ing manner. Coal is unloaded from the cars by crane to the stock pile, while a bulldozer continuously packs and grades the pile in convex layers of approximately 6 inches. See Fig. 18, above.

This pile must be carefully built to avoid fires because coal may not be removed from the pile for a period of years. Thus, thermocouples are installed at various points to determine when the pile becomes overheated and the resulting hot spots must be removed. This stock pile is located about 1200 feet from the plant.

Alongside the plant a storage pile of about 7,000 tons may be kept. Here, however, coal is constantly removed or added, therefore, careful building of this pile is very difficult to maintain. The pile is completely removed once a year so that no old coal is left on the bottom from one year to the next. This reduces the possibility of coal fires considerably.

<u>Coal Tests</u>

For all new coals that the purchasing agent may order, coal performance tests are made and a resulting report is sent to him concerning advisability of continuing purchase of said coal.

The tests are run for periods of 48 to 60 hours depending on operating conditions. During these tests, data for two or three different steady loads for periods of 8 hours or more are obtained besides the overall 24 hour periods.

Some of the data recorded and noted are firing characteristics at various loads, slaging effect, amount of ash, evaporation rate, fuel bed thickness, coal analysis, and cost of coal per thousand lbs. of steam. With this information and comparison between different coals the purchasing agent and power superintendent can chose the proper coal to be used.

Below is the chemical analysis of two typical coals in use at the present time.

	Coal A	Coal B
Moisture	1.76	1.51
Ash	10.03	8.82

	Coal A	Coal B
Volatile Matter	37.27	34.82
Fixed Carbon	50.99	54.85
Sulphur	2.80	1.26
BTU per lb. as fixed	12,948	13,326

Coal Problems

At the present there are three outstanding problems pertaining to coal. They are as follows:

1. Coal handling system.
2. Excessive fly ash and sulphur gases.
3. Possibility of dust explosions in bunker room.

Coal Handling

At the present time the plant is dependent on one coal elevator system and reliability of this system is very doubtful. In fact, we have had on one occasion to construct a temporary system to avoid a forced outage. (See Figs. 19 and 20, pages 54 and 55). On several other occasions employees have to work long hours.

To rectify this condition, it is recommended to install a bucket type coal elevator immediately. Then, eventually, when finances are available to install an incline belt conveyor. This conveyor would:

1. Allow the unloading and storage of coal some distance from the plant.
2. Increase reliability.
3. Decrease maintenance.
4. Improve plant appearance.

Excessive Fly Ash and Sulphur Gases

With our present low stacks and the forced draft fans taking their air supply from east side of the building causes

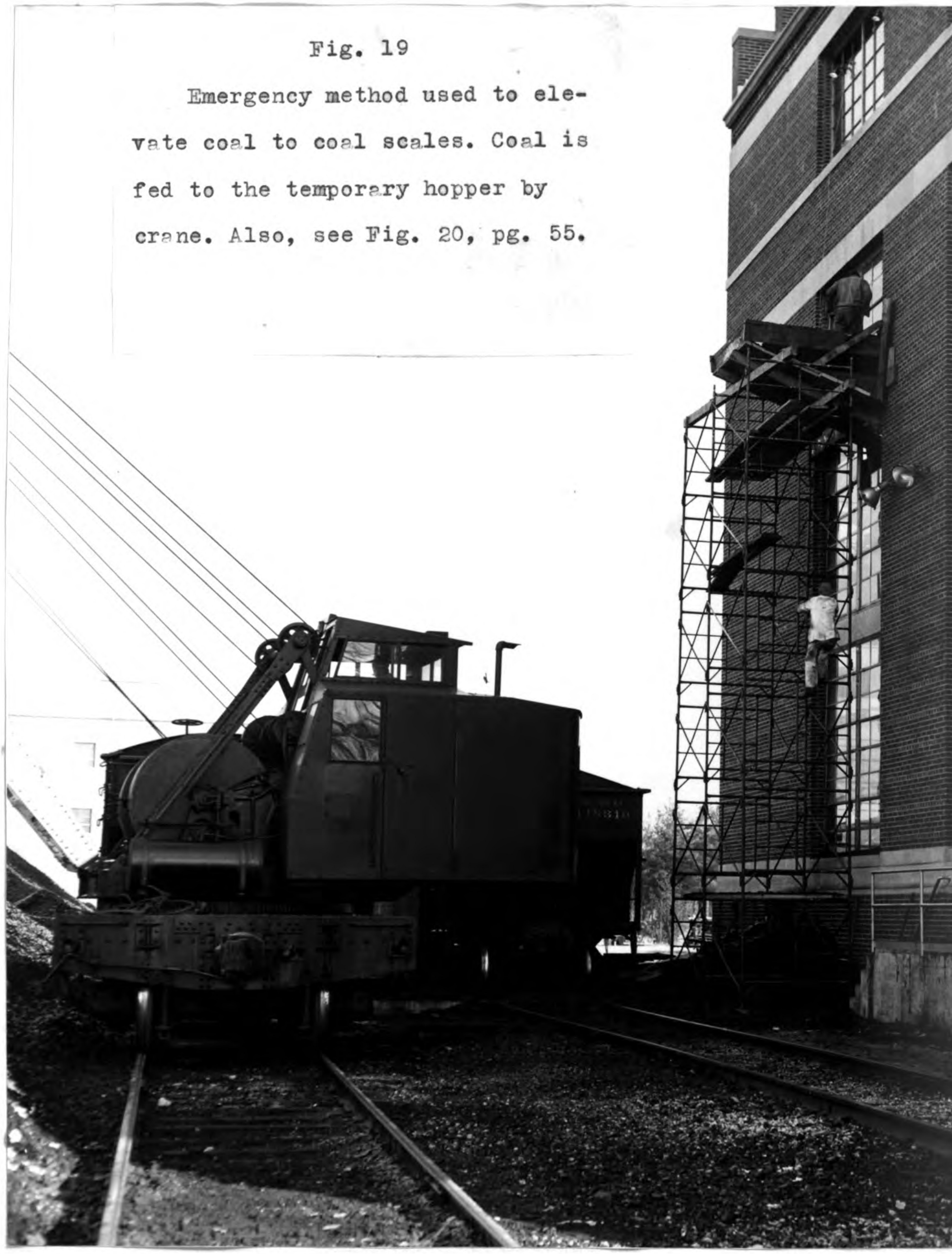

Fig. 19

Emergency method used to elevate coal to coal scales. Coal is fed to the temporary hopper by crane. Also, see Fig. 20, pg. 55.

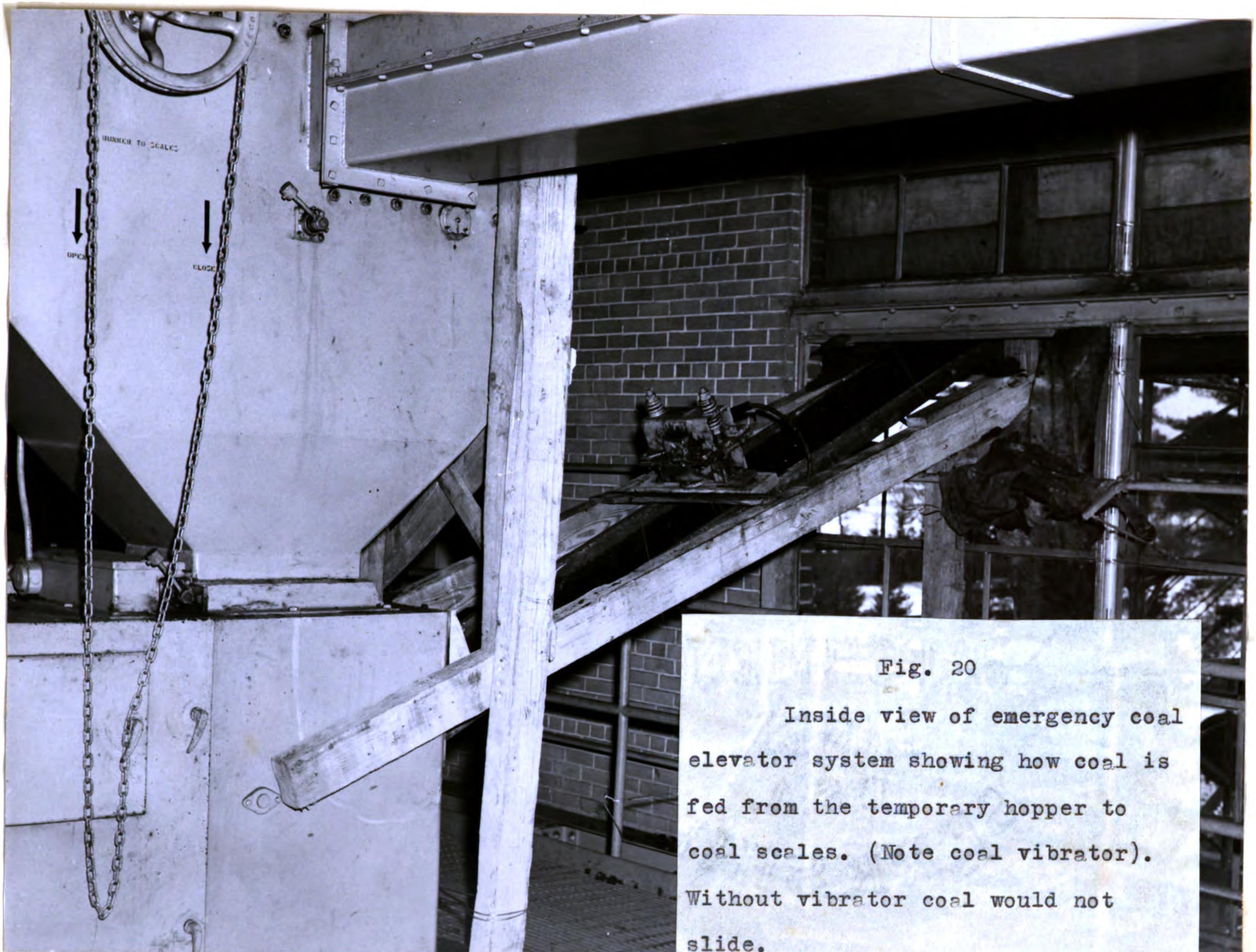

Fig. 20

Inside view of emergency coal elevator system showing how coal is fed from the temporary hopper to coal scales. (Note coal vibrator). Without vibrator coal would not slide.

the gases and fly ash to sweep toward the ground before they become defused. This makes very unpleasant atmospheric conditions in the surrounding area.

A 250 ft. stack will soon be built at the north end of the building to overcome this condition. This would make it possible to burn cheaper coals of higher sulphur content.

The fly ash problem is partially solved by removing the fly ash from the precipitator hopper by use of the ash system instead of re-injection. This decreases the amount of ash recirculating through the boiler considerably, consequentially, reduces the amount of ash thrown to the atmosphere.

<u>Possibility of Dust Explosion in Bunker Room</u>

At the present time the coal bunkers are open at the top and the surrounding room becomes filled with dust from falling coal as bunkers are filled.

Shortly a ventilating system will be installed. It will draw 3,000 c.f.m. continuously from the bunker room and discharge this air to the boiler secondary air system. In fact, the fan used will be the small secondary air fan. Also, a damper arrangement will be used where outside air or building air or a combination of both may be fed to the bunker room. When the new conveying system is installed a floor will be built above the bunkers, therefore, reducing the amount of dust considerably.

BOILER FEED WATER

Today, with the increase of technical improvements our feed water treating system is considered a fairly well designed plant. The desire to obtain the water treatment objectives (prevention of scale, corrosion, carryover, and caustic embrittlement)[12] are steadily:

1. Increasing the dependability of boiler service.
2. Decreasing repair costs of feed water lines, boiler tubes, heating system lines and auxiliaries, and condensate return lines.
3. Increasing the length of time a boiler can be on the line between extensive boiler cleaning periods.

However, it is to be kept in mind that correct design is only half the problem. The system must be operated correctly if the desired results are to be obtained. This may be accomplished by:

1. A complete understanding of the feed water system.
2. Proper check-ups and control at various key points in the system.

Feed Water System

The system consists of 80 percent return condensate and 20 percent make-up. The make-up feed is a blended hydrogen, sodium zeolite softened water. The blending is such as to produce a neutral water (P.H. 7.0).

After softening, the make-up is degasified and is mixed with the returning condensate in the deaerator heater. From here it goes to the boilers where chemical additions are made (sodium sulphite to reduce dissolved oxygen and disodium phosphate to reduce scale forming salts). A schematic feed water

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12. E.W. Feller, "Fundamental of Feed Water Treatment", Power Magazine, December, 1947.

system diagram is provided for a more complete picture. See Fig. 21, page 59.

Below is a chemical analysis before and after softening:[13]

	Report Units		Before Softening	After Softening Blended Water
Ph Value	Hydrogenion		7.4	7.0
Silica	SiO_2	ppm	12	16
Oxides	Fe_2O_3	"	1	1
Calcium	Ca	"	84	1
Sodium	Na	"	1	15
Magnesium	Mg	"	30	.2
Bicarbonate	HCO_3	"	382	41
Chloride	Cl	"	3	3
Sulphate	SO_4	"	15	20
Hardness	$CaCO_3$	"	333	4
Dissolved Solids	-	"	390	67.5

<u>Boiler Water Control</u>

The internal condition of the boilers depends on a ridged control of the feed water and continuous blowdown of operation boilers. This is done as follows:

1. Daily chemical analysis of all operating boilers. See Fig. 22, page 60.
2. Daily chemical analysis of boiler feed water.
3. Frequent check on each softener.
4. Correct balancing of Hydrogen to Sodium water.
5. Correct interpretation of all chemical analysis.
6. Controling of the continuous blowdown from each operating boiler.

With the correct correlation of the above data and proper control the boilers when secured for summer repairs were found in very good condition (See Fig. 23, page 61). In fact, it was

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13. Chemical analysis supplied by Hall Laboratories, March 22, 1949.

Fig. 21

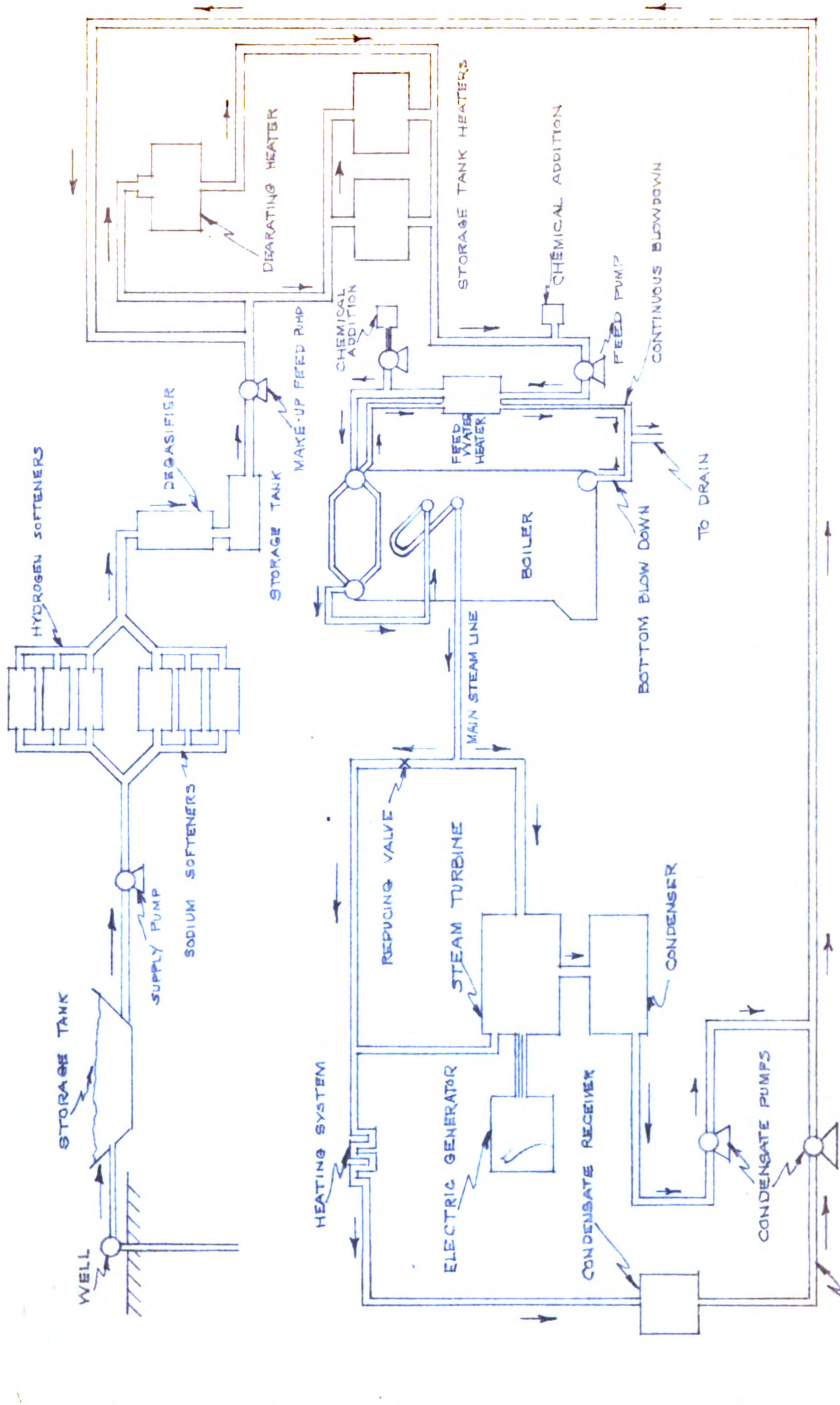

FIG. 14-II
FEEDWATER SYSTEM AT M.S.C. POWER PLANT

MICHIGAN STATE COLLEGE POWER PLANT
BOILER WATER REPORT

MONTHLY LOG

YEAR 1950
MONTH July

DAY	BOIL NO	WATER IN BOILERS: GRAINS PER GALLON					SOLIDS GRAINS PER GALLON							BOILER FEED WATER GRAINS PER GALLON				
		HARD	PHENOL	METHYL ORANGE	CHLOR	CONC	SODIUM HYDRATE	SODA ALK	SODIUM CARB	SODIUM SULPH	SULPHITE PPM	DIS SOL	PHOSPHATE PPM	GHO PT.	HARD	[illegible]	METH ORAN	CHLOR.
1																		
2																		
3	2	0	12	15.2	1.9										0	.1	1.0	.6
4																		
5	2	0	11.8	13.8	2.8	7.0	7.84	11.8	4.0	17.0	25.0		25.0	8.5	0	.1	.8	.4
6	2	0	11.2	14.0	2.9	7.2	6.72	11.2	5.6	18.0	20.0		25.0	8.5	0	.1	.7	.4
7	2	0	12.0	14.6	3.1	7.7	7.52	12.0	5.2	19.0	23.0		25.0	8.5	0	.1	.5	.4
8																		
9																		
10	2	0	14.8	17.5	3.7	12.3	9.76	14.8	5.2	24.0	40.0		55.0	8.5	0	.1	.5	.3
11	2	0	16.0	19.0	3.5	8.7	10.40	16.0	6.0	22.0	31.0		55.0	8.5	0	.1	.7	.4
12	2	0	16.0	19.0	3.6	9.0	10.40	16.0	6.0	23.0	30.0		50.0	8.5	0	.1	.9	.4
13	2	0	17.2	20.0	3.7	9.2	11.52	17.2	5.6	22.0	27.0		45.0	8.5	0	.1	1.0	.4
14	2	0	16.0	19.0	4.2	8.4	10.40	16.0	6.0	24.0	40.0		35.0	8.5	0	.1	1.0	.5
15	2	0	17.8	20.8	3.2	8.0	11.84	17.8	6.0	26.0	47.0		35.0	8.5	0	.1	.7	.4
16																		
17	2	0	16.2	21.8	4.1	10.2	8.48	16.2	11.2	29.0	79.0		50.0	8.5	0	.1	.9	.4
18																		
19	2	0	16.0	19.8	4.4	11.0	9.76	16.0	7.6	28.0	75.0		50.0	8.5	0	.2	1.0	.4
20	2	0	19.0	24.0	5.3	10.6	11.20	19.0	10.0	37.0	107.0		45.0	8.5	0	.1	.9	.5
21	2	0	13.8	16.8	3.0	7.5	8.64	13.8	6.0	24.0	43.0		45.0	8.5	0	.1	.9	.4
22	2	0	14.2	15.6	2.5	6.2	10.24	14.2	2.8	19.0	34.0		40.0	8.5	0	.1	.9	.4
23																		
24	2	0	16.0	18.0	3.0	7.5	11.20	16.0	4.0	20.0	20.0		30.0	8.5	0	.1	1.0	.4
25																		
26	2	0	18.2	20.8	2.6	8.6	12.48	18.2	5.2	27.0	24.0		25.0	8.5	0	.1	1.1	.3
27	2	0	18.0	20.6	3.0	7.5	12.42	18.0	5.2	31.0	27.0		30.0	8.5	0	.1	1.0	.4
28	2	0	24.6	31.2	6.8	13.6	14.40	24.6	13.2	47.0	High60		25.0	8.5	0	11	1.4	.5
29																		
30																		
31	2	0	11.8	13.2	3.5	8.7	8.32	11.8	2.8	17.0	23.0		30.0	8.5	0	.1	1.2	.4
AVER	2	0	15.6	18.7	3.5	8.8	10.18	15.6	6.1	24.9	39.7		37.8	8.5	0	.1	.9	.4

FIG. 22

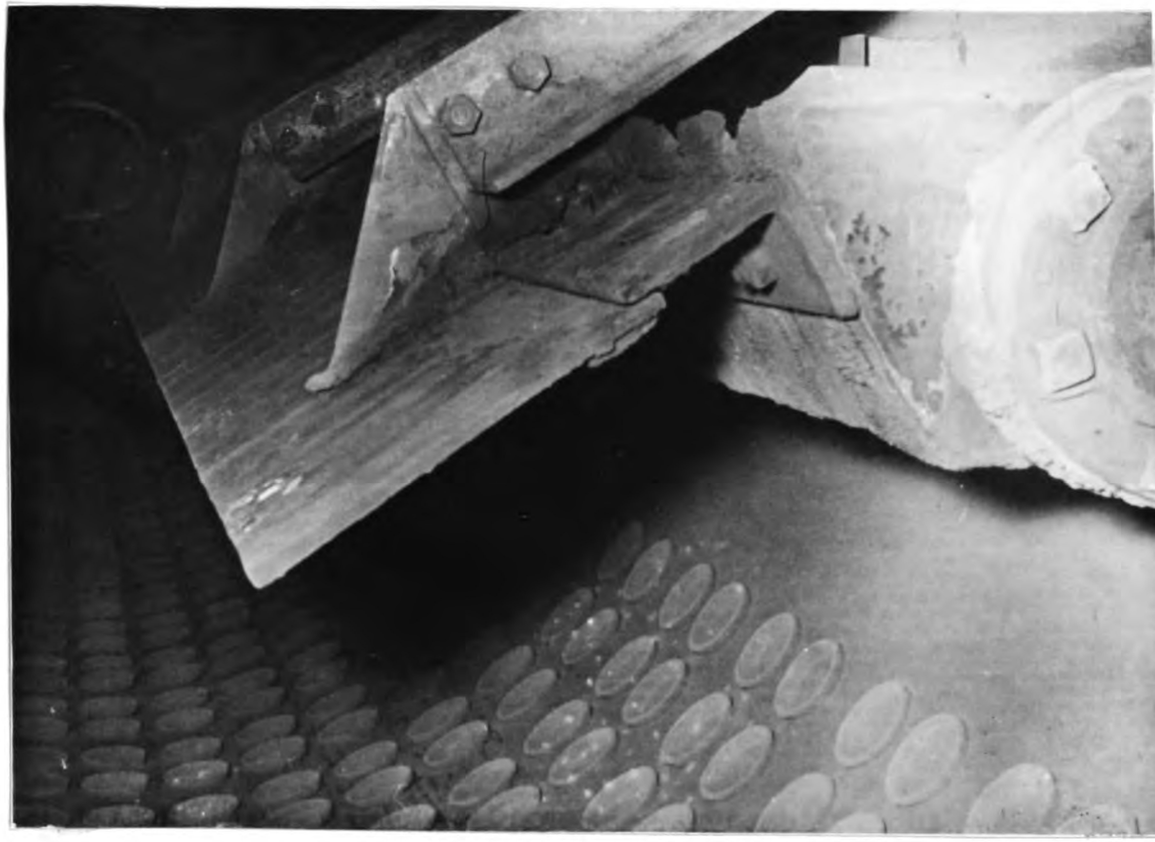

Fig. 23

Internal view of rear steam drum after 9 months service before cleaning.

recommended by the water consultant[14] to only wash the boilers down. Thus, by proper feed water control a large economical and time savings may be accomplished.

Feed Water Problems

Following is a list of existing feed water problems:

1. Daily water control.
2. Inadequate Hydrogen softened water supply.
3. Lack of water sampling connections in condensate return line.
4. Inadequately trained personnel.

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14. Mr. Jones of Hall Laboratories.

5. Individual continuous blowdown control.

Daily Water Control

At the present time water samples are taken and tested only during the week. Thus, Saturday, Sunday, and holiday control is lacking. Much can happen during these periods such as, loss of chemical control, scaling of boilers, low or high alkalinity, etc.. All which may well take a week to get back to proper control.

Therefore, for proper control, thus, an economical savings, a daily test and interpretation should be taken. However, this would mean another qualified water technician.

Inadequate Hydrogen Softened Water

At the present time, number 1 and 2 Hydrogen softeners cannot produce their rated supply of softened water (18,000 gals.). This is due to attrition losses throughout the years. Consequentially, at times of heavy demand the hydrogen soften water supply will not meet the demand.

Thus, it is recommended that the present zeolite be replaced with new or that a new 36,000 gal. unit be installed in the near future.

Lack of Water Sampling Connections in Condensate Return Lines

The main sources of water contamination is from the condensate returns from hot water heaters. As there are several hundred such heaters installed on the campus, many of which are twenty or more years old, it is almost impossible to sample each heater for raw water contamination.

Accordingly, a water sampling connection should be installed at the outlet of each building before the junction to the condensate return line. By sampling here only the one buildings' water heaters would have to be checked, thus, reducing the amount of time involved considerably and greatly reducing the possibility of forming scale in the boilers.

Inadequately Trained Personnel

At the present time only one adequately trained technician handles the feed water system. If he is sick, on vacation, etc., there is no trained person to carry on. Therefore, we need to train a substitute for this job. Also, with two trained men we could have samples taken and run daily.

In the near future a suitable person should be trained for this position. This man would more than pay his wages in plant reliability and resulting economy.

Individual Continuous Blowdown Control

Under normal operation (two boilers) at the present time the continuous blowdown from each boiler is connected to one heat exchanger. Thus, one boiler bucks the other. That is, if one boiler has a slightly higher load, thus a higher pressure, it tends to reduce the flow from the other boiler. This in turn makes it very hard to properly control the amount of blowdown necessary for proper boiler water regulation.

It is recommended in the near future a second heat exchanger be installed. This would make possible one heat exchanger for each boiler continuous blowdown. In the system the coolent (feedwater) should be connected in series (see Fig. 24, page 64). In the writers' opinion this would give the most

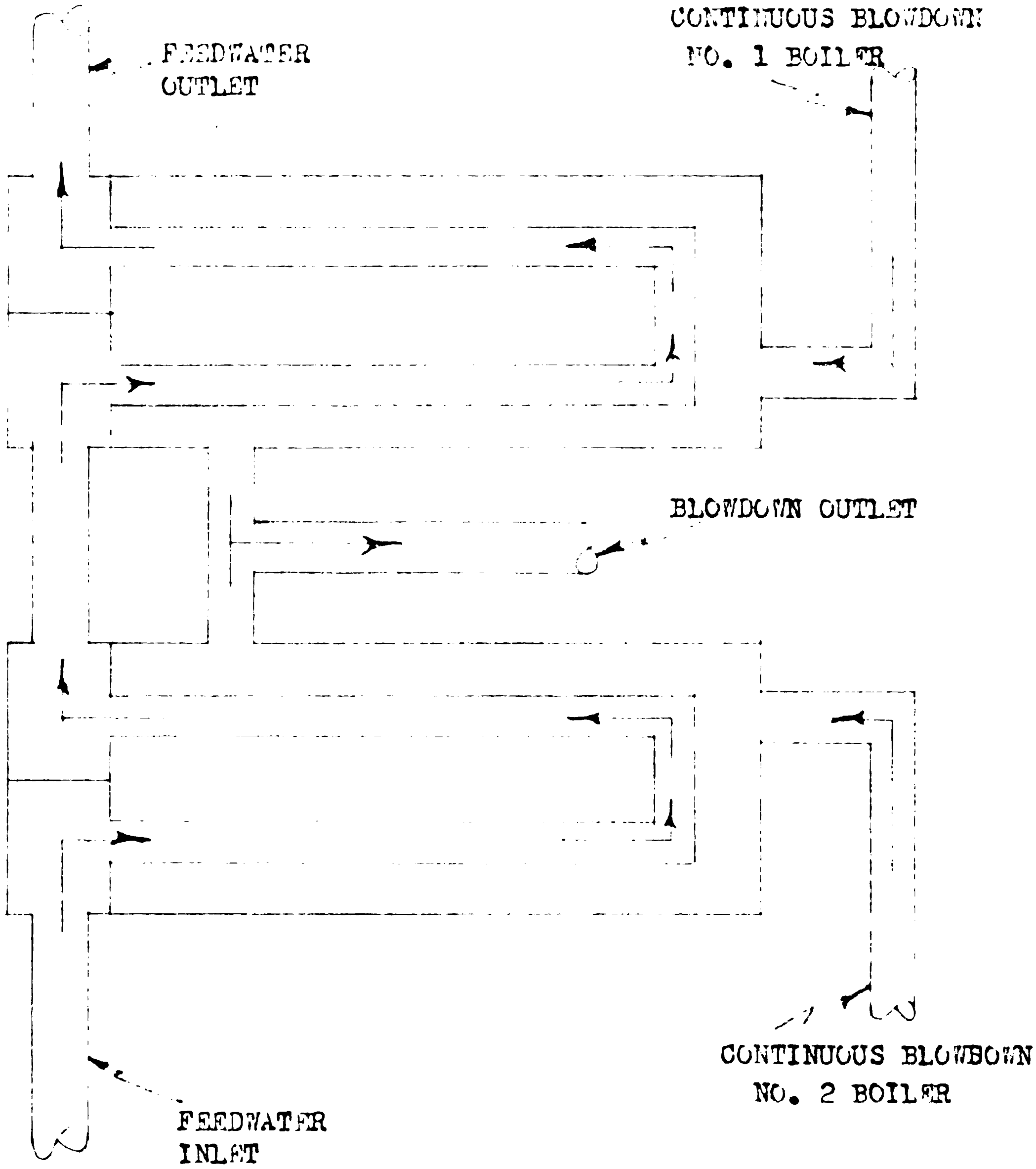

FIGURE 24

SCHEMATIC DIAGRAM OF PROPOSED CONTINUOUS BLOWDOWN
HEAT EXCHANGER SYSTEM

satisfactory result, because in the parallel system the coolent outlet of one or the other heat exchanger would have to be throttled as it would be very difficult to obtain the same resistance in each exchanger.

PART III

PLANT MAINTENANCE

From the day of initial operation the keeping of the plant in good operating condition is a problem. Therefore, preventive maintenance and effective maintenance procedures must always be practiced if the ultimate plant objective is to be maintained.

MAINTENANCE PERSONNEL

The life and operational reliability of the plant and its equipment partially depend on the maintenance personnel. Therefore, great care should be taken in picking this personnel. Consequentially, it is felt that qualified men must have the following prerequisites and be properly trained:

1. Practice good house-keeping habits.
2. Have mechanical abilities.
3. Like to repair old equipment.
4. Be a power plant operator.
5. Be able to think.

MAINTENANCE PROCEDURES

Proper maintenance procedures tend to reduce operation outages, operation costs, and increasing overall plant efficiencies and reliability. Thus, objectives of the maintenance program are:[15]

1. To keep equipment in serviceable condition.
2. To reduce emergency outages to an economic minimum.

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15. E.R. Spencer, Maintenance of Pumping Station Equipment, page 240. Mount Vernon, Ohio: The Cooper-Bessemer Corporation.

3. To keep the cost of such maintenance within reasonable economic limits.

<u>Major Repair Periods</u>

Because the plant must operate at or near full production from October through May, it is necessary to inspect and overhaul the entire plant during the summer months. As this is a relatively short period it is well to make maintenance preparations well in advance.

Therefore, it is necessary to:

1. Make all possible repairs or changes during the heating season.
2. Practice preventive maintenance to the maximum economical extent.
3. Have adequate amount of spare parts and materials on hand.
4. Keep records of previous work done.
5. Keep records of work to be done.
6. Estimate amount of hours needed per job.
7. Estimate amount of time each piece of major equipment must be out of service.

A complete explanation of the above items may be found under other headings in this chapter.

<u>Building Maintenance</u>

Besides the initial building investment, the plant's reputation is greatly effected by its general appearance. So, the building must be maintained internally and externally. Thus, building maintenance procedures should contain the following items:

1. Practice preventive maintenance.

2. Practice cleanliness and orderliness.

Practice Preventive Maintenance

Often if a small repair is made in time it may save much larger and costlier repairs. Therefore, it is necessary to inspect the building periodically and make necessary repairs as soon as possible. That is, if by periodical inspection a small plumbing leak is found, it should be fixed. If the leak is neglected it may become larger, allowing water to stain or destroy furnishings whose cost of repair or replacement is much greater than the cost of inspections and immediate repairs.

Practice Cleanliness and Orderliness

Besides improving the general appearance of the building, cleanliness and orderliness may reduce building maintenance costs, improve safety conditions, and reduce overall operation costs.

That is, if floors, steps, machinery, etc., are kept clean abrasive wear will decrease and faulty items are easier to locate. Also, keeping tools, ladders, and other equipment in designated places will decrease maintenance time and accidents. Broken windows, electric light bulbs should be immediately replaced and paint work kept in good condition. Consequently, the results are economical savings and increased plant appearances (see Fig. 25, page 69).

Maintenance Room

It is in this room that a large amount of the repair work is performed. Therefore, it should be adequate, clean, orderly,

Fig. 25

View of basement showing cleanliness and orderliness. Note painted alley ways.

and conveniently available for the majority of repair jobs. See Fig. 26, page 70.

Equipment

The maintenance room should be large enough to contain all necessary repair equipment. For safety, ample working space and convenience of cleaning of machinery, lathes, grinders, welders, drill presses, etc., should not be crowded together.

Also, portable hand tools such as pipe wrenches, electric hand drills, special wrenches, etc., should have a definite lo-

Fig. 26

View of plant maintenance room. Repairman on the left is taking spare parts inventory while workman at table is repairing a valve.

cation in the shop and should be returned to this location when not in use. This serves two purposes:[16]

1. Gives a check on the equipment.
2. Eliminates the time wasted in looking for equipment when the next man starts a job.

Fig. 27, page 71, shows a picture of a tool cabinet used

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16. H.E. Rumpf, "Effective Maintenance Procedure", National Engineer, vol. 54 (September, 1950), page 23.

Fig. 27

Hand tool cabinet. Also, note repairman checking part list inventory records.

in the south campus plant.

__Storage__

Adequate storage space for spare parts and materials should be conveniently located, in, or near the maintenance room, and be kept in an orderly fashion. Pipe should be neatly kept on pipe racks, and pipefittings, nipples, valves, bolts and nuts, packings should be stored in suitable bins. It is well to have all bins marked with size and item which it contains.

Along with the storage of spare parts an inventory record of all such parts be kept. This record should contain the location of storage. For the convenience of ordering parts, it should show amount on hand, and the maximum and minimum number normally carried in stock. Such a file in use is shown in Fig. 27, page 71.

The necessity in stocking spare parts is obvious if continuity of service is to be maintained. Therefore, the following factors may help in determining the quantity of repair parts to be kept on hand:[17]

1. Cost of out of service time.
2. Distance from source of material and manufacture's ability to supply.
3. Different types of equipment.
4. Frequency of certain failures.
5. Advantages in quantity purchases.

Preventive Maintenance

Preventive maintenance is the practice of frequent periodical inspections and check-ups of the plant and its equipment; followed by the repair of all faulty equipment at this time.

In the well organized plant the "fix it when it quits" method is obsolete. Thus, it has been proven that periodic inspections, adjustments, and repairs are the most economical.

In the south campus plant the following preventive practices are used:

1. Scheduled major maintenance inspection and overhaul

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17. E.R. Spencer, Maintenance of Pumping Station Equipment, page 241. Mount Vernon, Ohio: The Cooper-Bessemer Corporation.

periods.

2. Greasing and oiling check off system.

3. Weekly building and equipment inspections.

MAINTENANCE RECORDS

The maintenance record is a written life history of all major equipment. Its objective is to increase the reliability, economy, and efficiency of the plant. By continuously studying these records:

1. Forced outages may be reduced by proper preventive maintenance.

2. Increase in economy may be realized by finding means to reduce frequent part replacements.

3. Efficiencies may be increased by scheduled periodical inspections and overhauls.

Essentially, these records should include the date of original installation, all details on which information may be wanted at any time, and a subsequent record of all labor and materials spent on the piece of equipment in question.

<u>Value of Maintenance Records</u>

To receive full value of maintenance records they must be used. They should not just be filed away for future reference. By carefully analyzing these records, they will be helpful in determining the following items:

1. Maintenance cost of equipment.

2. To estimate length of time and man hours needed for overhaul periods.

3. To estimate plant budget.

4. To determine the necessary work to be performed dur-

ing overhaul periods.

5. To plan operation time in hours between necessary equipment inspections and overhaul periods.

6. To determine which workman made necessary repairs.

7. The planning of plant training programs.

8. To determine dates when major changes or extensive overhauls were performed.

9. To determine when repairs are excessive and parts or equipment should be replaced.

10. Used as a guide for manufacturers in designing new equipment.

11. To determine when changes in operation procedures may reduce maintenance.

12. To determine the number of maintenance men required.

13. To prove the advantages of practicing preventive maintenance.

Maintenance Forms and Records

To give full value, maintenance forms must contain accurate and complete information, be up to date, be simple in form and readily accessible. They should contain the following types of forms:

1. Machinery history forms.
2. Maintenance record forms.
3. Repair cards.
4. Inventory cards.
5. Part list cards.

Machinery History Forms

This form or forms should include the date of original installation, by whom installed, and all essential details of the machinery, driver unit, and drive control unit. Examples of such forms may be found inside the back cover.

Maintenance Record Forms

It is this form which should include all necessary repairs for the above machinery history forms. It should include equipment, names, date, workmans' name, and the work done. Also, preferable, but not absolutely necessary, the amount of hours neede to perform the necessary repairs. Such a form may be found inside the back cover.

Repair Cards

When it becomes evident that equipment needs repair this fact should be written down although it may be quite sometime before repairs may be made. Thus, some form of a repair card should be used. Such a card should include equipment name, date, description of work needed, actual work performed, parts or materials used, and repairmans' signature. Then, after the job is completed, this card may then be used to complete the machinery history record. An example card is shown in Fig. 28, page 76.

Inventory Cards

As it is necessary to keep a complete record of spare parts on hand some conventional form should be used. Such a form must contain equipment name, part and part number, maximum and minimum number to be on hand, the amount on hand, and where it is kept. Fig. 29, page 76, shows an example of the card used in the south campus plant.

Fig. 28

REPAIR CARD

Equip. Name: Low Level Conveyor
Date Issued: 8/11/50 When Work is to be done:
Date Completed: 8/14/50
Description of Work: Install new shaft, new bearings, new sprocket. Also check drive end for wear.

Workman's Remarks: Completed above work. Found drive end in good condition. Also found coal chain badly worn.

Workman's Signature: L. Hamilton
List parts or materials used on reverse side.
(6002)

Fig. 29

Max 18
Part Stoker Grate Bar No. 43256X32 Min 8

Date	Rec'd.	Used	On hand
3/12/49	---	---	12
5/ 1/49	6	---	18
5/27/49	---	8	12
7/ 6/49	---	6	6
7/30/49	12	---	18
10/11/49	---	2	16
3/ 2/50	---	2	14
5/ 7/50	6	---	20
6/21/50	---	8	12
8/ 1/50	---	10	2
8/21/50	16	---	18

Part List Cards

A complete part list for each piece of equipment should be kept. This card should include part name and number, catalog number, units per machine, cost per unit, and where to order the part.

Procedure of Maintenance Record System

By the practice of preventive maintenance it is found that a general inspection is needed for, let us say, number 3 Boiler Feed Pump. A repair card is made out stating same and given to the maintenance foreman who:

1. Checks the inventory list for all available parts.
2. Receives necessary information for ordering parts from the part list and machinery history files.
3. When all necessary materials are on hand he then assigns job and card to repairman.

This repairman who performs necessary work then:

1. Checks off all parts used from inventory list.
2. Writes parts and materials on repair card.
3. Writes all other necessary information on repair card when the job is completed, signs, and lists all men who have worked on job.
4. Returns card to maintenance foreman.

The maintenance foreman then:

1. Checks work.
2. Checks inventory record against parts used.
3. Has card information added to the maintenance record, after which the card is then destroyed.

Thus, it is seen how the maintenance record system may be

used to an advantage over mental noting of what needs maintenance or what maintenance has been completed.

MAINTENANCE PROBLEMS

Maintenance problems may be reduced by adequate maintenance personnel, proper maintenance schedules, proper records, and being provided with a well designed maintenance room.

Adequate Maintenance Personnel

When the plant labor budget is inadequate, it is usually the maintenance personnel that is reduced. Therefore, it should be shown by properly kept records the amount of personnel needed to adequately maintain the plant, if reliability, efficiency and economy is not to be sacrificed.

Proper Maintenance Schedules

As production is increased and the plant tends to reach its maximum capacity, maintenance schedules become a problem. Therefore, it is recommended that adequate records are kept showing need and saving made by proper schedules versus buying power during these repair periods. It is the writers' opinion under no conditions should the practice of preventive maintenance be neglected.

Maintenance Room

The maintenance room in the south campus plant is not adequate. It is not large enough, properly vented or lighted. The ash hoppers form one side of the room. Therefore, when the boilers are operating the room is too hot in which to comfortably work.

For these reasons it is recommended, if a plant addition is ever built that provisions be made for a well adapted maintenance room and connecting storage facilities.

Records

From time to time due to lack of adequate personnel, it is a great temptation to neglect the records. This is a mistake as the value of records is unlimited. Therefore, under no conditions should record keeping be neglected.

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M A I N T E N A N C E   R E C O R D

Equip. Name Number 1 Stoker

DATE	Workman	Work Done
7/27/49	Hamilton	Checked and replaced 32 twyeres in stoker. Cauked and cemented in twyeres.
8/ 5/49	Fink	Inspected grates, grate chains, and grate chain pins. Replaced 1 grate. Found otherwise in good condition.
8/10/49	Detroit Stoker	Put new seals in stoker and lined up fly ash returns.
8/17/49	Louie	Inspected and renewed fly ash returns as necessary. Lined up air nozzles.
9/22/49	Vilmont	Welded leak in fly ash return from north precipator hopper.
9/26/49	Green	Changed couplings both sides #2 stoker.
9/26/49	Green	Found coal distribution dusting nut sheared. Put in new pin.
10/31/49	Green	Tightened up chains and went over stoker. Found in good shape.
11/10/49	Hamilton Detroit Stoker	Put new front air seals in stoker. Old ones were raised too high and lost seal. Detroit Stoker put old and new ones in.
11/11/49	Ryal	Raised south air heater fly ash return line and put in new nozzle.
11/11/49	Ryal	Raised reaves drive.
11/15/49	Hamilton	Changed around 2 grate guides and changed 3 other grate guides.
11/15/49	Green	Inspected piv units. Change pitch chain in northside of motor unit. Tightened other chains.

(6001)

NEW POWER PLANT

INDUCED DRAFT FAN NO# 1

FAN RECORD

NAME INDUCED DRAFT FAN NO# 1

LOCATION NORTHERN CORNER, TOP FLOOR, ON NO# 1 BOILER

MANUFACTURER CLARAGE FAN COMPANY

TYPE OF FAN TYPE OF DRIVE MOTOR

TYPE NO. RT. SIZE 12

FIG NO. MODEL NO.

C.F.M. MAX. DESIGN 89,300

SPEED 1180/580 SERIAL NO. 15184F

OTHER DATA:

ASSEMBLY SECTION DWG. NO. U-4724-1 (BOILER INSTRUCTION BOOK)

SPARE PARTS BULLETIN NO.

TYPE OF COUPLING FAST COUPLING

NO. OF COUPLING BUSHINGS/SET NONE

SIZE OF COUPLING BOLTS NONE

RECOMMENDED PACKING NONE

NO. RINGS INSIDE LANTERN GLANDS NONE

O. D. OF SHAFT AT SLEEVE 7 3/4 IN.

INBOARD BEARING NO.

O. D. OF JOURNAL 3.9375

TYPE OF BEARING SLEEVE

TYPE OF LUBRICATION OIL

KIND OF LUBRICANT STANDARD OIL NO# 51

(6158)

NEW POWER PLANT

NO#1 COAL SCALES

METER RECORD-COAL SCALES

MAKE SE CO AUTOMATIC COAL SCALES INSTALLED 1948

RANGE 200LBS TO 8 TONS PER HR. BEAM RATIO

TYPE AUTOMATIC MODEL 46

SERIAL NO. 1017A GUARANTEED ACCURACY WITHIN 2 LBS

LOCATION SECOND LEVEL IN FRONT OF NO1 BOILER

REMARKS: SCALE GREASE STAN OIL FACTO LUB 2

WIRING DIAGRAM NO D 1298

INSTRUCTION BOOK PARTS LIST OF SE CO AUTOMATIC COAL SCALES

COAL SCALE DUMP COUNTER

NATIONAL ACME CO

SERIAL NO. R.A. 1956

VOLTS 110 AMPS 2.5

CYCLES 60

(6162)

NO#1 CO_2

NEW POWER PLANT

METER RECORD CO_2 RECORDERS

MAKE HAYS CLOCK TYPE 110 V. 60C LOCATION

INSTALLED 1948 RANGE 0-19 CHART NO. 10063

PANEL TYPE MODEL SERIAL NO.

RECORDER TYPE X MODEL CDPR SERIAL NO. CDPR 100847S

INDICATOR TYPE MODEL SERIAL NO.

SIZE, LENGTH AND KIND OF CONNECTING PIPE COPPER TUBING 92 FT. 1/8"

LOCATION AND KIND OF SAMPLING TUBE SOOT FILTER (CARBORUNDUM)

LOCATED AT BEGINNING OF PREHEATER NO 525

ELECTRIC POWER SUPPLY VOLTS 110 CYCLE 60

INSTRUMENT REQUIREMENTS " " " "

INSTRUMENT TRANSFORMER NO NONE

(6161)

MISCELLANEOUS EQUIPMENT RECORD

NAME AIR COMPRESSOR NO#1

LOCATION NORTH END OF BASEMENT ON EAST SIDE

SERVICE AIR FOR CONTROL

MANUFACTURER WORTHINGTON PUMP AND MACHINERY CORP.

INSTALLED BY INSTALLATION DATE 1/15/49

PARTS BULLETIN NO. 11-620-E29 DWG. NO.

INSTRUCTION BULLETIN NO. NONE

NAME PLATE DATA:

SIZE 6 x 3 1/2 x 2 3/4 2 CYCLINDERS (227)

CAT. NO. AIR KING SER. NO. CAPACITY

OTHER DATA AIR COMPRESSOR OIL, SHELL AIR COMPRESSOR OIL

MODEL 15 T 276

RUNNING TIME 1 MINUTE ON, 2 MINUTES OFF 5/26/49

PRESSURE SWITCH

STYLE HU 1

FURNAS ELECTRIC COMPANY

BATAVIA, ILL.

(6163)

NEW POWER PLANT

MOTOR CONTROL RECORD

CONTROLLED UNIT NO#1 AIR COMPRESSOR MOTOR

CONTROL APPARATUS

TYPE 110 VOLTS 60 CYCLE TYPE NO.

MANF. G.E. H. P.

VOLTS 600 AMPS. 60

PHASES 3 CYCLES 60

CAT. NO SERIAL NO.

COIL CAT. NO. 22-D-1126-G-2 D. L. NO.

THERMAL O. L. 81-D-257 O. L. HEATER NO. 81-D-257

WIRING DIAG. NO.

INSTRUCTION BULLETIN NO.

PARTS BULLETIN NO.

OTHER DATA SQUARE D MAG. STARTER ON COMP. CLASS CL 8536

TYPE SA TA & UA COIL# CLASS 170781--T26A 440V.

DISCONNECTING DEVICE G.E. COMBINATION STARTER

TYPE OF SWITCH G.E. TYPE NO

MANUFACTURER G.E.

VOLTS 600 AMPS 60

NO. POLES 3 FUSE SIZE 60

CAT. NO.

FED FROM TRANSFORMER

OTHER DATA

(6159)

NEW POWER PLANT

MOTOR RECORD

NAME NO#3 BOILER FEED PUMP MOTOR

LOCATION MAIN FLOOR, THIRD PUMP FROM SOUTH END OF PUMP BAY

MANUFACTURER GENERAL ELECTRIC

SERVICE DRIVE NO#3 FEED PUMP

TYPE OF MOTOR	INDUCTION	TYPE	K CODE F
FORM		MODEL	5 K1405 A 2
FRAME	4055	STYLE	
H.P.	60	K.W.	
E/S.		M/S.	
VOLTS	440	AMPS.	72
SIZE		SPEED	3555
CYCLES	60	PHASES	3
SERIAL NO.	TD 6709229	WINDING	DELTA
DUTY	CONTINUOUS		

OTHER DATA:

CONNECTION TO LOAD GEAR COUPLING

BEARING NO. 6966156-1

TYPE OF BEARING SLEEVE

TYPE OF LUBRICATION OIL

KIND OF LUBRICANT STAN. OIL 25

SHAFT SIZE 1.875

INSTRUCTION BULLETIN NO.

SPARE PARTS BULLETIN NO.

(6160)

NEW POWER PLANT

PUMP RECORD

NAME NO#3 BOILER FEED PUMP LOCATION

MANUFACTURER MAIN FLOOR, THIRD PUMP FROM SOUTH END OF PUMP BAY

TYPE OF PUMP DE LAVAL STEAM TUR. CO. TYPE OF DRIVE MOTOR

TYPE NO. 60 M 3P3/ 2 1/2 SIZE 32/2 1/2

FIG. NO. MODEL NO.

G.P.M. 117 FT. HEAD 905

SPEED 3550 SERIAL NO. 250140

OTHER DATA DISCHARGE PRESS, 391 PSIG. SUCTION PRESS. 16.6PSIG

ASSEMBLEY SECTION DWG. NO. E 15000

SPARE PARTS BULLETIN NO. INSTRUCTION BOOK DRG. NO. E 15000

TYPE OF COUPLING WALDRON STANDARD GEAR SIZE 2A. 1/4 PINT OF OIL

NO. OF COUPLING BUSHINGS PER SET NONE

SIZE OF COUPLING BUSHINGS O.D. NONE I.D. LGTH.

SIZE OF COUPLING BOLTS 1 BY 3/8

RECOMMENDED PACKING ANCHOR 317

SIZE PACKING 3/8

NO. RINGS INSIDE LANTERN GLAND 2 OUTSIDE 3

O.D. OF SHAFT AT SLEEVE 2001

INBOARD BEARING NO. 563 OUTBOARD BEARING NO. 563

O.D. OF JOURNAL 1496

TYPE OF BEARING SLEEVE

TYPE OF LUBRICATION OIL

KIND OF LUBRICANT STAN. OIL # 25

SUCTION VALVE CHAPMAN GATE DIA. 3" IN

DISCHARGE VALVE CHAPMAN GATE DIA. 2 1/2

CHECK VALVE CHAPMAN GATE DIA. 2 1/2

(6157)