FE-2652-T7
Distribution Category UC-90e

PROTOTYPE ANTHRACITE CULM COMBUSTION BOILER/HEATER UNIT, CITY OF WILKES-BARRE, PENNSYLVANIA

QUARTERLY TECHNICAL REPORT NO. 4,

JULY 1 - SEPTEMBER 30, 1979

PREPARED FOR

THE DEPARTMENT OF ENERGY

UNDER DOE CONTRACT NO. ET-78-C-01-2652

BY

CITY OF WILKES-BARRE

WITH

POPE, EVANS AND ROBBINS INCORPORATED

AND

FOSTER WHEELER BOILER CORPORATION

TABLE OF CONTENTS

LIST OF EXHIBITS

ABSTRACT

There are currently about 910 million cubic yards of anthracite culm (mine refuse) contained in 800 separate banks in a 480 square mile area in the Wilkes-Barre (W-B) anthracite mining region. Although this material represents a significant fuel value, equivalent to approximately 1.25 billion barrels of fuel oil, the culm banks have accumulated because no satisfactory method of combusting this fuel was available until the relatively recent development of the atmospheric fluidized bed (AFB) steam generator.

A program was initiated in October 1978 to design, construct and evaluate a 100,000 pph AFB steam generator burning anthracite culm with the addition of fresh anthracite, if required. The unit is to demonstrate the technical, economical and environmental feasibility of producing 150 psig saturated steam for district heating in downtown W-B.

Phase I of the program consists of the design of the atmospheric fluidized bed (AFB) plant and a hot model test program.

Phase II of the program consists of construction, operation, testing and evaluation of the boiler and boiler plant.

PROGRAM OBJECTIVES AND SCOPE

OBJECTIVES

The objectives of this program are:

1. Establish the technical and economic feasibility of firing anthracite culm in an AFB steam generator producing steam for district heating in downtown W-B.
2. Establish the relationships among the variables of excess air, bed temperature, culm analysis, heating value, and limestone to culm ratio in order to identify commercially acceptable operating conditions for the combustion of anthracite culm/anthracite mixtures in an AFB steam generator.
3. Limit sulfur dioxide and nitrogen oxide emissions to current air quality standards of 1.2 and .7 $lb/10^6$ Btu respectively.

SCOPE

The AFB steam generator will be located in a boiler plant formerly owned by the Stegmaier Brewery Co. and presently owned by the City of Wilkes-Barre. Culm will be reclaimed from culm banks in the W-B area. Where applicable, existing systems and equipment for materials receiving, handling and storage and existing buildings shall be utilized as part of the plant design. All work shall be performed in accordance with two distinct phases as follows:

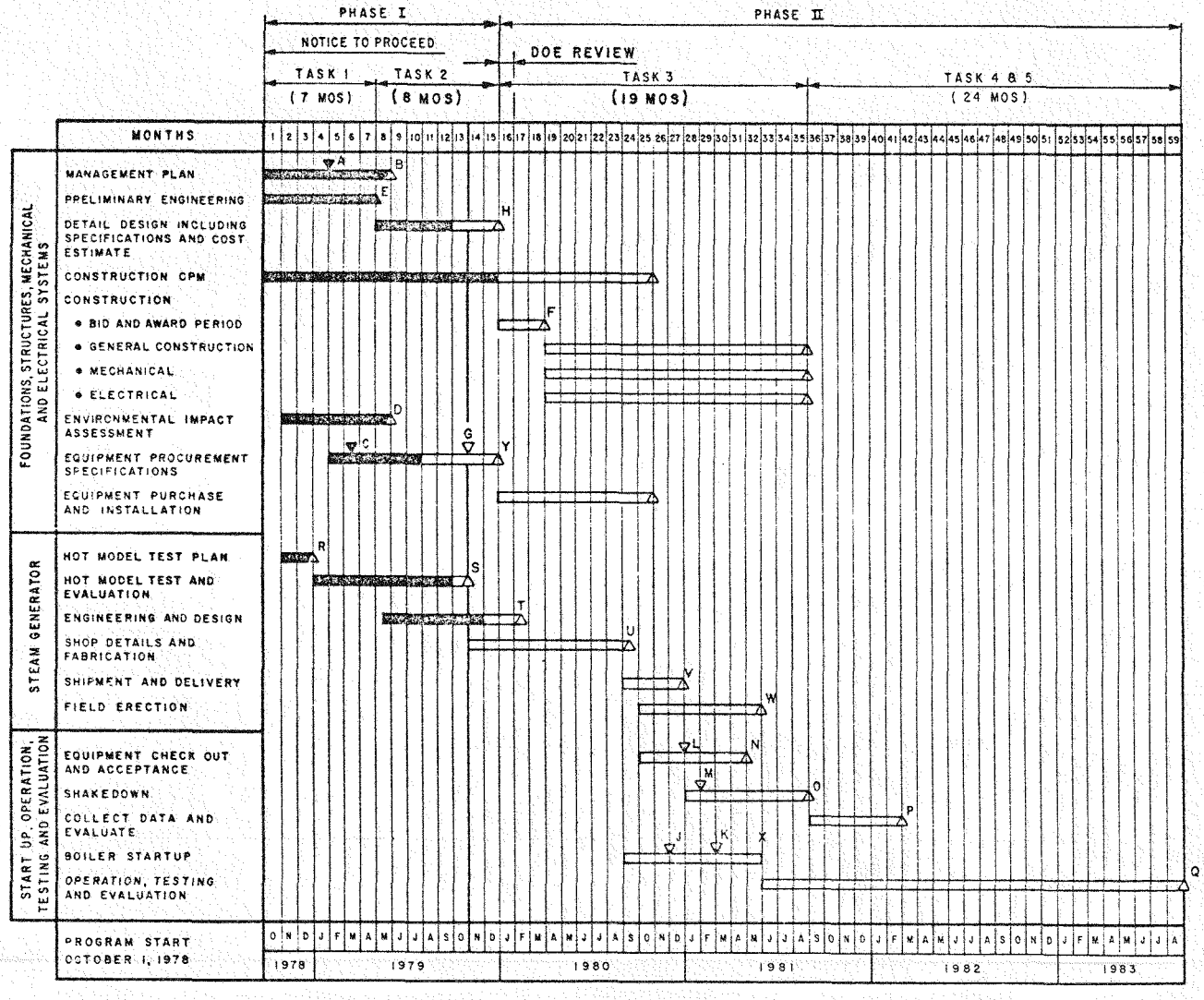
Phase I - Development Engineering and Design

This phase consists of all necessary engineering and design work prior to construction of the AFB steam generator and facility. The estimated period of performance of Phase I is fifteen months. The term includes time allowed for hot model testing, process selection, approval of designs, plans, specifications, construction bid packages, and the placement of subcontracts for long lead equipment items required under Phase II.

Phase II - Construction, Operation, Testing and Evaluation

This phase consists of equipment procurement, construction, operation, testing and evaluation of the AFB steam generator and facility. The total estimated period of performance is 44 months, consisting of a 20 month construction task and 24 months for operation testing and evaluation. (See Exhibit A).

PROGRAM SCHEDULE AND MILESTONE REPORT



NOTES

A. SUBMIT PROGRAM PLAN CPM (2/8/79)
B. SUBMIT MANAGEMENT PLAN
C. SUBMIT PRELIMINARY EQUIPMENT LIST (2/8/79)
D. SUBMIT ENVIRONMENTAL IMPACT ASSESSMENT
E. SUBMIT PRELIMINARY ENGINEERING REPORT (5/4/79)
F. COMPLETE BIDDING AND AWARD CONSTRUCTION CONTRACTS
G. SUBMIT LONG LEAD EQUIPMENT SPECIFICATIONS
H. SUBMIT FINAL CONSTRUCTION CONTRACT DOCUMENTS
J. SUBMIT STARTUP PROGRAM
K. BEGIN BOILER START UP
L. SUBMIT EQUIPMENT ACCEPTANCE PLAN
M. SUBMIT EQUIPMENT SHAKEDOWN PLAN
N. SUBMIT EQUIPMENT CHECKOUT AND ACCEPTANCE REPORT
O. SUBMIT REPORT OF SHAKEDOWN TESTS
P. SUBMIT OPTIMIZATION REPORT
Q. SUBMIT FINAL REPORT
R. SUBMIT HOT MODEL TEST PLAN (1/9/79)
S SUBMIT HOT MODEL TEST AND EVALUATION REPORT
T. COMPLETE BOILER ENGINEERING AND DESIGN
U. COMPLETE BOILER SHOP FABRICATION
V. COMPLETE SHIPMENT OF BOILER PARTS
W. COMPLETE BOILER ERECTION
X. COMPLETE BOILER START-UP
Y. APPROVAL FOR PROCURMENT SPECIFICATIONS

LEGEND

SCHEDULED ACTIVITY
COMPLETED ACTIVITY
MAJOR MILESTONE
SCHEDULED ▽ ▼ COMPLETED
INTERMEDIATE EVENT

EXHIBIT "A"

SUMMARY OF PROGRESS DURING THIS REPORT PERIOD

A. Hot Model Testing

1. The 100 hour verification test burning the Kaminski Bank culm was completed and results were forwarded to Foster Wheeler performance engineering personnel for their use in the boiler design. The 100 hour verification test results indicate that the carbon combustion efficiency drops from the 85.7% value observed during the batch tests to 82% for the same performance conditions (8 ft./sec. fluidizing velocity, 1750°F bed temperature, and flyash recycle).

2. The writing of the Hot Model Test and Evaluation Report was initiated during this report period and work is continuing. The report is scheduled to be issued during October, 1979. With the issuance of this report, the Hot Model Testing activity will be completed.

3. Samples of Kaminski Bank anthracite culm were sent to private testing facilities for determination of ultimate analysis and higher heating value (HHV). The results were evaluated and a representative ultimate analysis and associated HHV was selected for use in constructing a material balance.

B. Boiler Design

1. A preliminary general arrangement drawing of the boiler elevation, plan, and front views was completed and issued. Subsequent revisions to this drawing were issued which showed modified cell plan areas, a modified inlet air ductwork arrangement, and a modified grid plate arrangement.

a. The modified cell plan areas resulted from adjusted fluidizing velocities based on the 100 hour verification test results which showed a noticeable drop in carbon burnup efficiency from that evidenced in the batch tests. The plan areas had to be increased in order to establish an 8 ft./sec. fluidizing velocity and the corresponding 82% carbon burnup efficiency.

b. The inlet air ductwork arrangement was simplified based on the incorporation of three in-duct burners in lieu of a single in-duct burner.

c. As a result of concerns regarding temperature gradients and boiler startup, a water-cooled grid plate was selected in lieu of a "nut and bolt" and sparger tube design.

d. A startup system consisting of three (3) in-duct burners and six (6) ignitors was selected. An ignitor is located at each end of the three cells in order to provide adequate heat input to the bed. The three in-duct burners are located in the ductwork leading to each of the three cells in order to provide a source of hot air to prevent cool down of the bed during startup.

2. Work was initiated and is continuing on writing the specification for the Combustion Controls and Furnace Safety System. Work was also initiated on writing the Ignitor and In-Duct Burner specifications.

3. Design parameters were established and forwarded to PER for their use in sizing auxiliary equipment and checking plant layout.

4. Work was initiated on the boiler general arrangement "Shop Manufactured and Vendor Supplied Parts" drawing.

5. Work is proceeding on the detailed design of the boiler pressure part circuitry and heat transfer surface selection.

C. Final Design

1. Mechanical

(a) Prepurchase equipment specifications were initiated. Alternate feed systems were evaluated. Discussions were held with Ducon Company to determine if Ducon could provide a competitive feed system to the Fuller-Kinyon system.

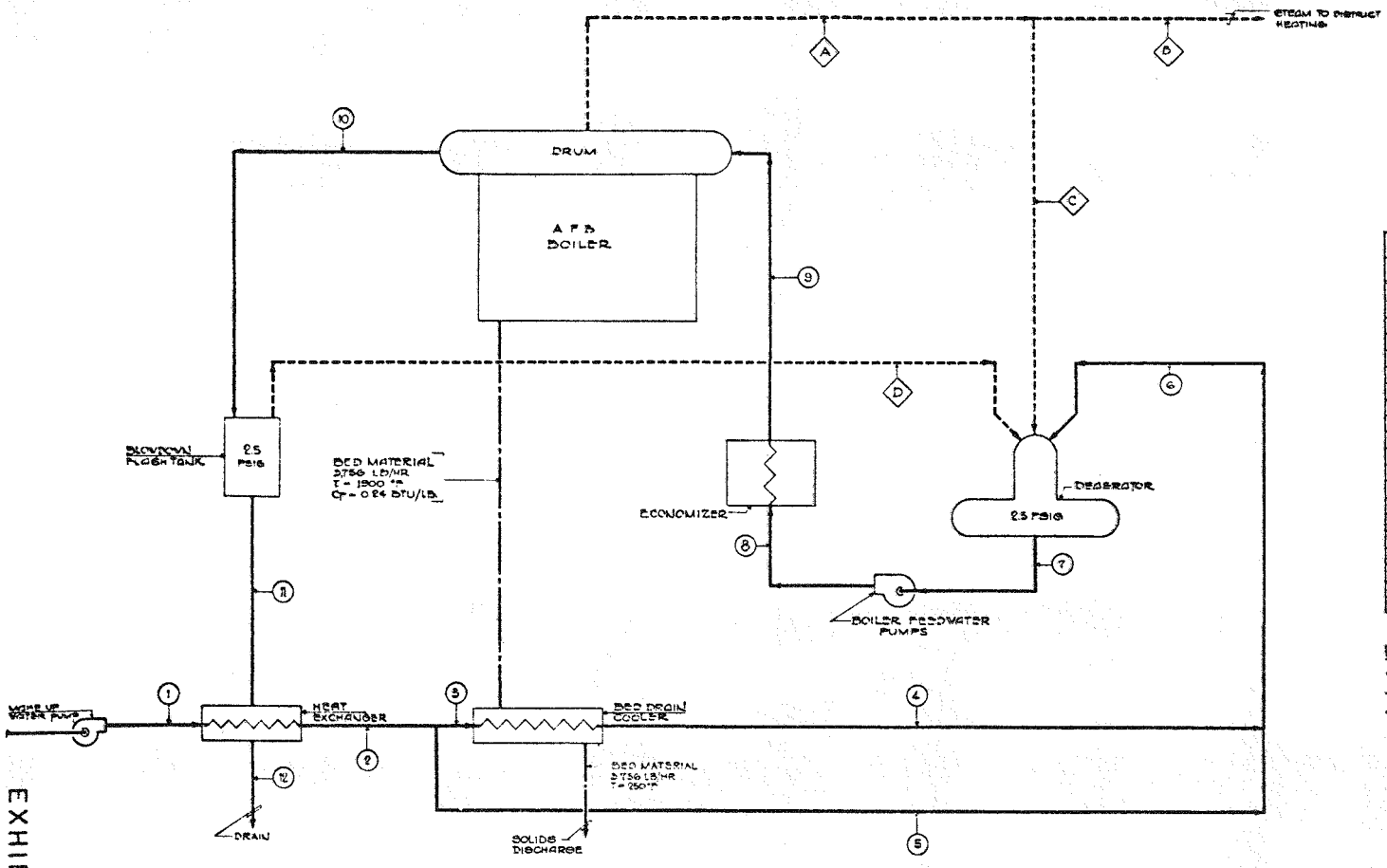
(b) Technical specifications for mechancial equipment and construction were initiated.

(c) The Heat Flow Diagram-Steam/Water Circuit, the Heat Balance Diagram, and the Material Balance Diagram were completed. See Exhibits 2-3, 2-4 and 2-5.

(d) Final plant design continued through this report period. Mechanical design and detailing were brought to near completion, however, equipment arrangements were modified to agree with boiler modifications initiated by Foster Wheeler as a result of information derived from the 100 hour test run. The boiler size and the start up system was modified. Three in-duct burners and 6 gas fired ignitors were added as part of the modified start up system. The size of the I.D. and F.D. fans were increased as a result of the boiler modifications. See Exhibits 2-2A, 2-2B, 2-8A, 2-8B, 2-8C, 2-8D, 2-8E, 2-9A, 2-9B, 2-9C and 2-9D.

(e) Process and Instrumentation Diagrams (P&ID) were initiated.

HEAT FLOW DIAGRAM STEAM-WATER CIRCUIT



HEAT BALANCE SCHEDULE

STREAM	FLOW (LB/HR)	TEMP (°F)	ENTHALPY (BTU/LB)	PRESS/VACUUM	REMARKS
1	91,510	50	18.07		
2	91,510	55	22.69		
3	57,562	55	22.69		
4	57,562	82	50.21		
5	33,948	55	22.69		
6	91,510	72	39.93		
7	105,000	220	188.13	2.5	
8	105,000			160	
9	105,000	345	316.38	150	
10	5000	366	338.54	150	
11	4,222	220	188.13	2.5	
12	4,222	120	87.92		
A	100,000	366	1195.57	150	
B	87,288	366	1195.57	150	
C	12,712	366	1195.57	150	
D	778	220	1153.4	2.5	

LEGEND

- LIQUID
- VAPOR
- SOLIDS
- (1) LIQUID IDENTIFICATION
- (A) VAPOR IDENTIFICATION

EXHIBIT 2-3

POPE, EVANS AND ROBBINS

HEAT BALANCE DIAGRAM

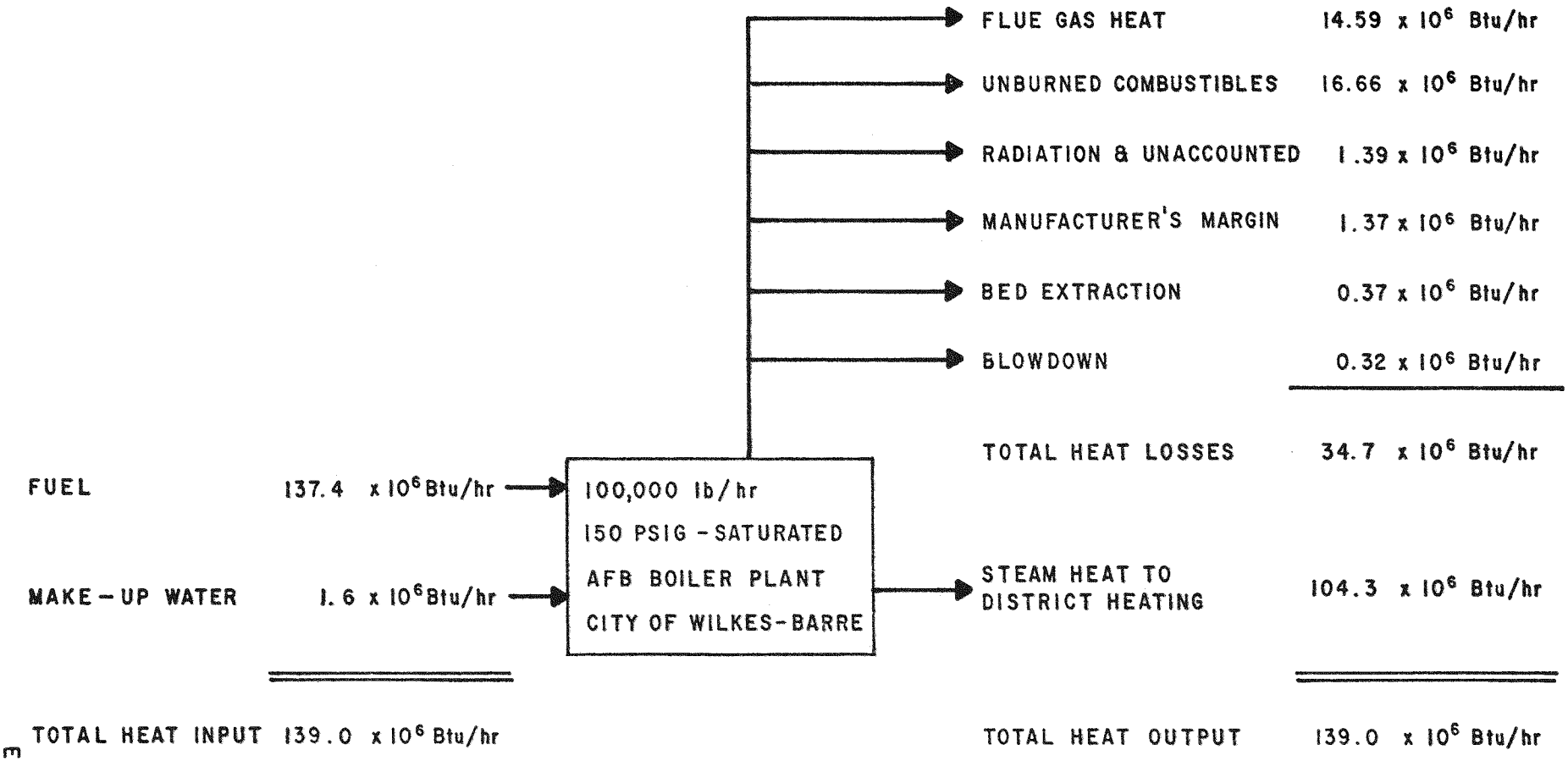
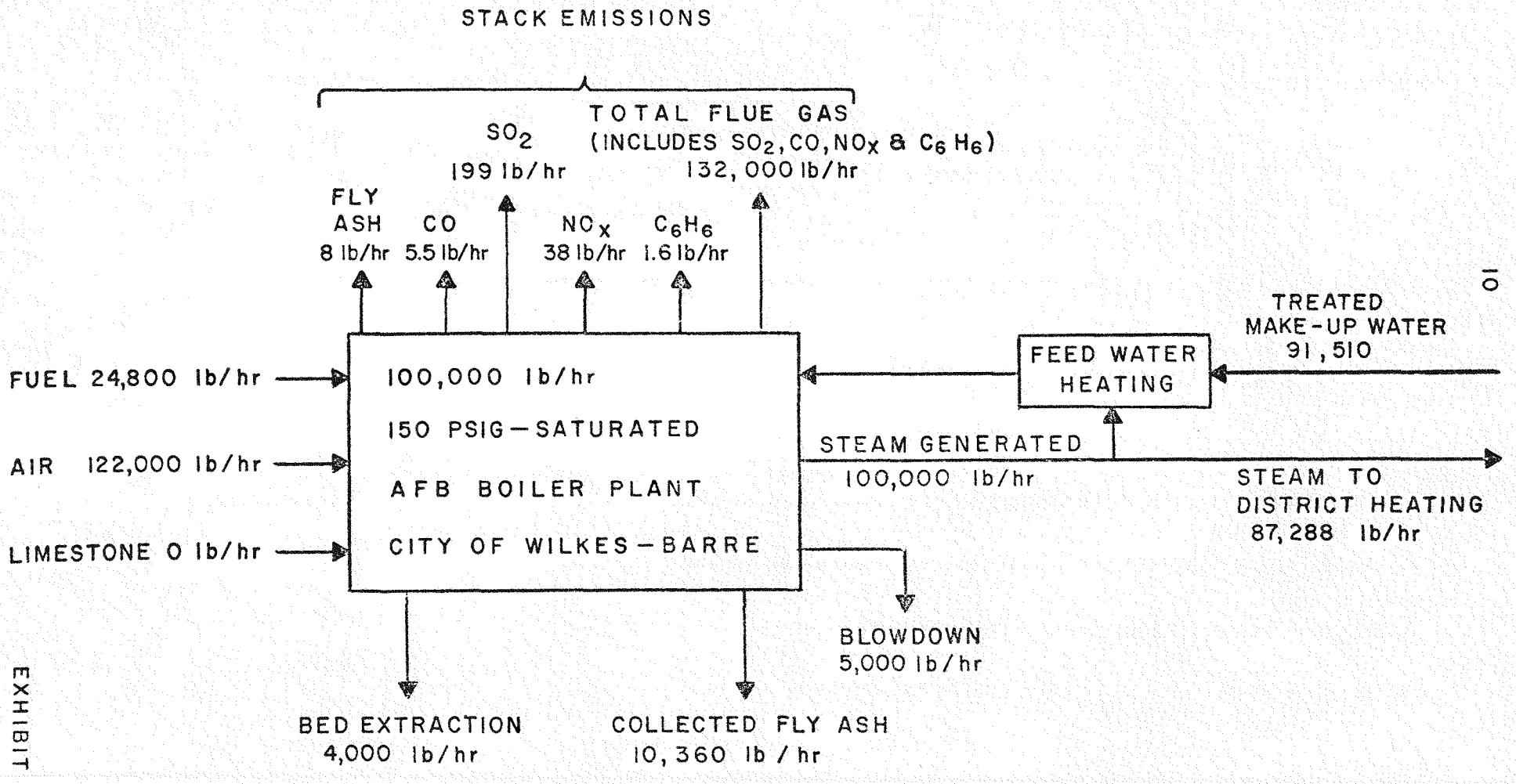


EXHIBIT 2-4

POPE, EVANS AND ROBBINS

MATERIAL BALANCE DIAGRAM



POPE, EVANS AND ROBBINS

EXHIBIT 2-5

2. Electrical

   (a) Technical specifications were initiated.
   (b) Electrical design and detailing was initiated.
   (c) One-line diagrams were brought to near completion and elementary wiring diagrams initiated. See Exhibits 3-1A, 3-1B and 3-1C.

3. Structural

   (a) Structural technical specifications were initiated.

   (b) Structural design was brought to near completion and the detailing initiated. See Exhibits 4-1A, 4-1B and 4-2A.

4. Architectural

   (a) Architectural specifications were initiated.
   (b) Architectural details were further developed. See Exhibits 5-1A and 5-2A.

D. Environmental

Prevention of significant Air Quality Deterioration (PSD) Application to EPA and Application for Plan Approval to Construct, Pennsylvania DER, have been submitted based on final results of the Foster Wheeler 100 hour test.

E. Demolition

Demolition has been completed for one existing boiler, and has nearly been completed on the second existing boiler. The City of Wilkes-Barre personnel will continue on the demolition program till the end of the year attempting to remove as many items as is possible in the way of the new construction.

F. Subsurface Investigation At AFB Boiler Plant Site

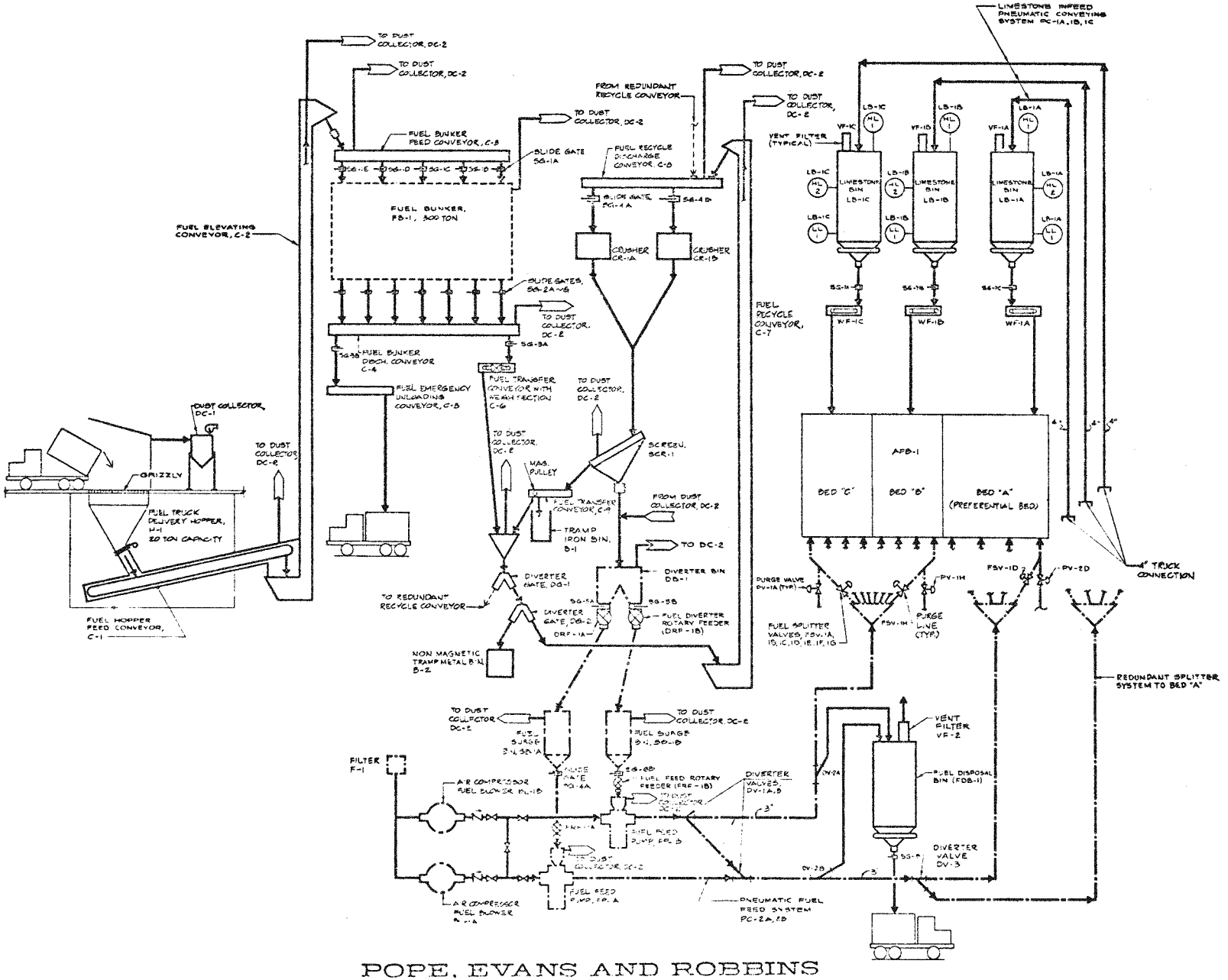
F.T. Kitlinski and Associates completed the soils boring and testing program and the results were submitted to PER in report form. The investigation generally concluded that the natural alluvial soils which comprise all but the upper few feet of the overburden will form an excellent bearing stratum for supporting spread footings and foundation pads. Based on a minimal embedment of five feet, the calculated maximum allowable soil-bearing pressure for spread footings and foundations wholly supported by natural alluvial soils is 10,000 psf. However, due to the erratic extent and quality of upper fill deposits, it may be necessary to found some of the structures partly or wholly on compact select granular material in order to achieve a uniform, relatively shallow foundation level. Under these circumstances, the maximum allowable soil-bearing pressure for compacted select granular material should be limited to 3000 psf.

Based on the information accumulated in conjunction with the preliminary study of the underground mining conditions, it is concluded that the risk of future subsidence at the site due to past mining activities is negligible.

G. Status of Property Acquisition

W-B has received approval from the City Council for the purchase of properties required for access to the plant and construction of facilities. The acquisition has been minimized to include only those properties which are absolutely necessary for access, construction and operations. Some residences will still remain adjacent to the plant. See Exhibits 2-6 and 2-7.

FLOW DIAGRAM - PLANT FEED SYSTEM



POPE, EVANS AND ROBBINS

EXHIBIT 2-2A

FLOW DIAGRAM - GAS AND SOLIDS REMOVAL SYSTEM

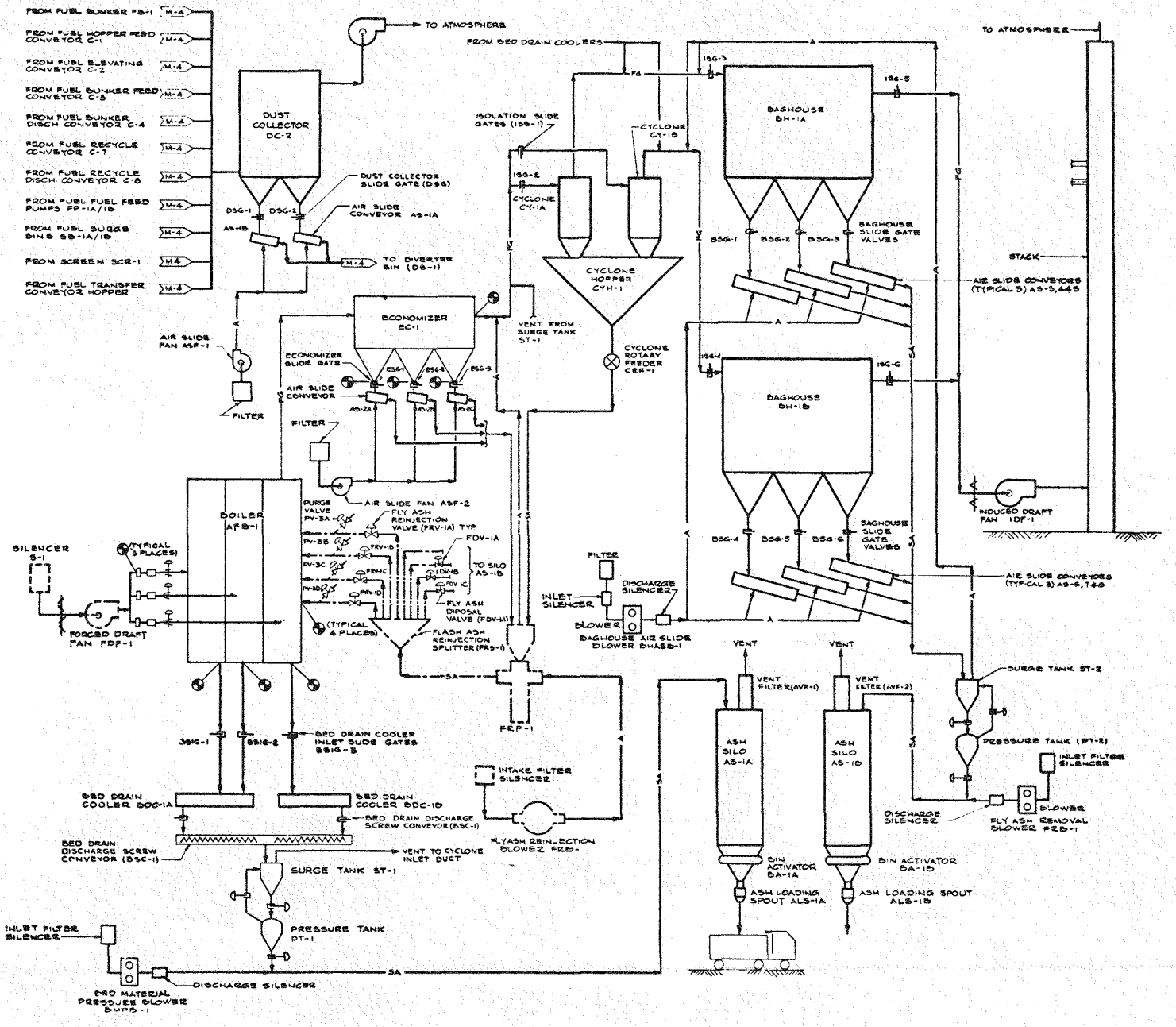


EXHIBIT 2-2B

MECHANICAL GENERAL ARRANGEMENT PLAN
EL. 0'-0"

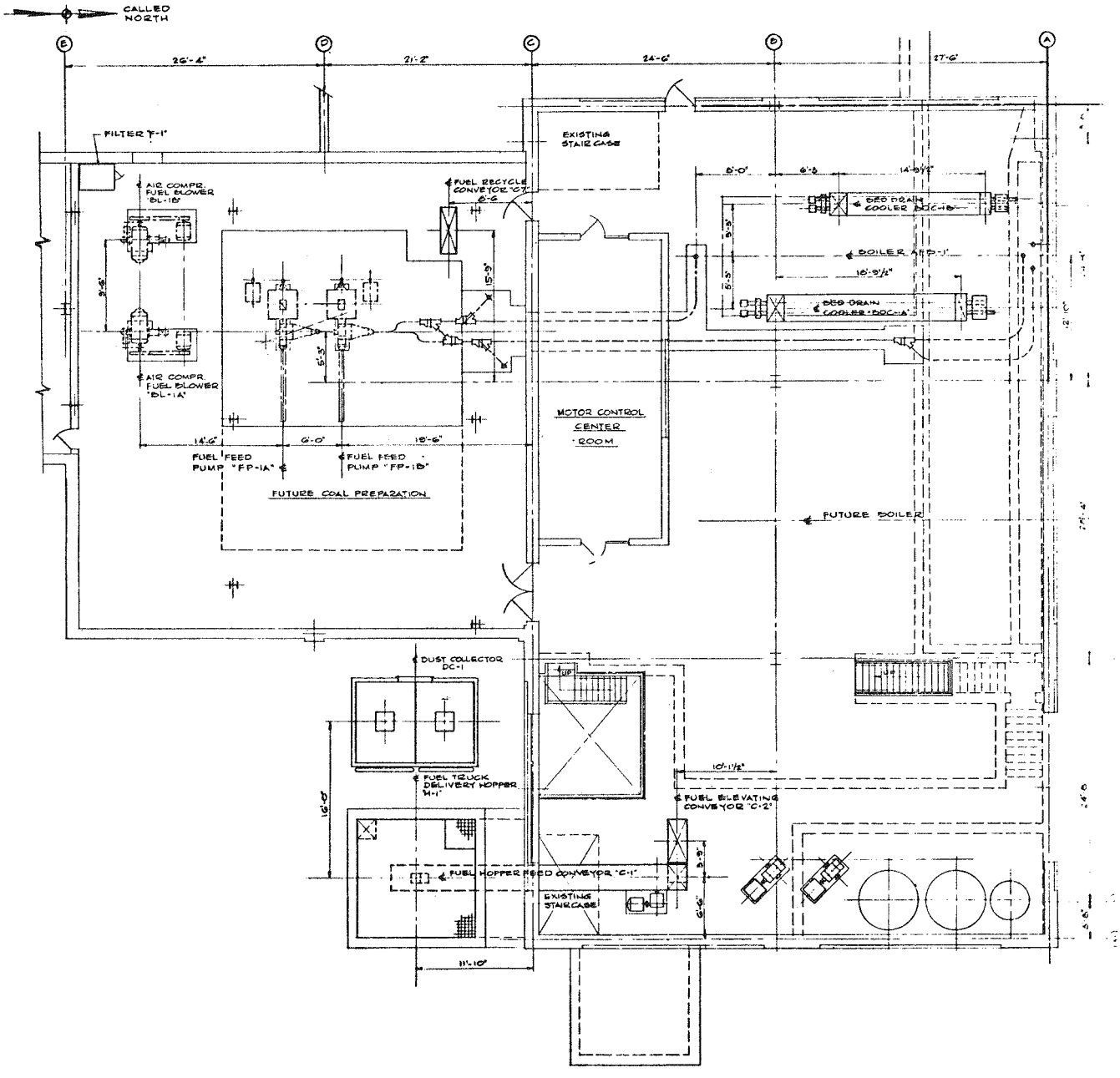


EXHIBIT 2-8A

MECHANICAL GENERAL ARRANGEMENT PLAN
EL. 10'-0" & 36'-0"

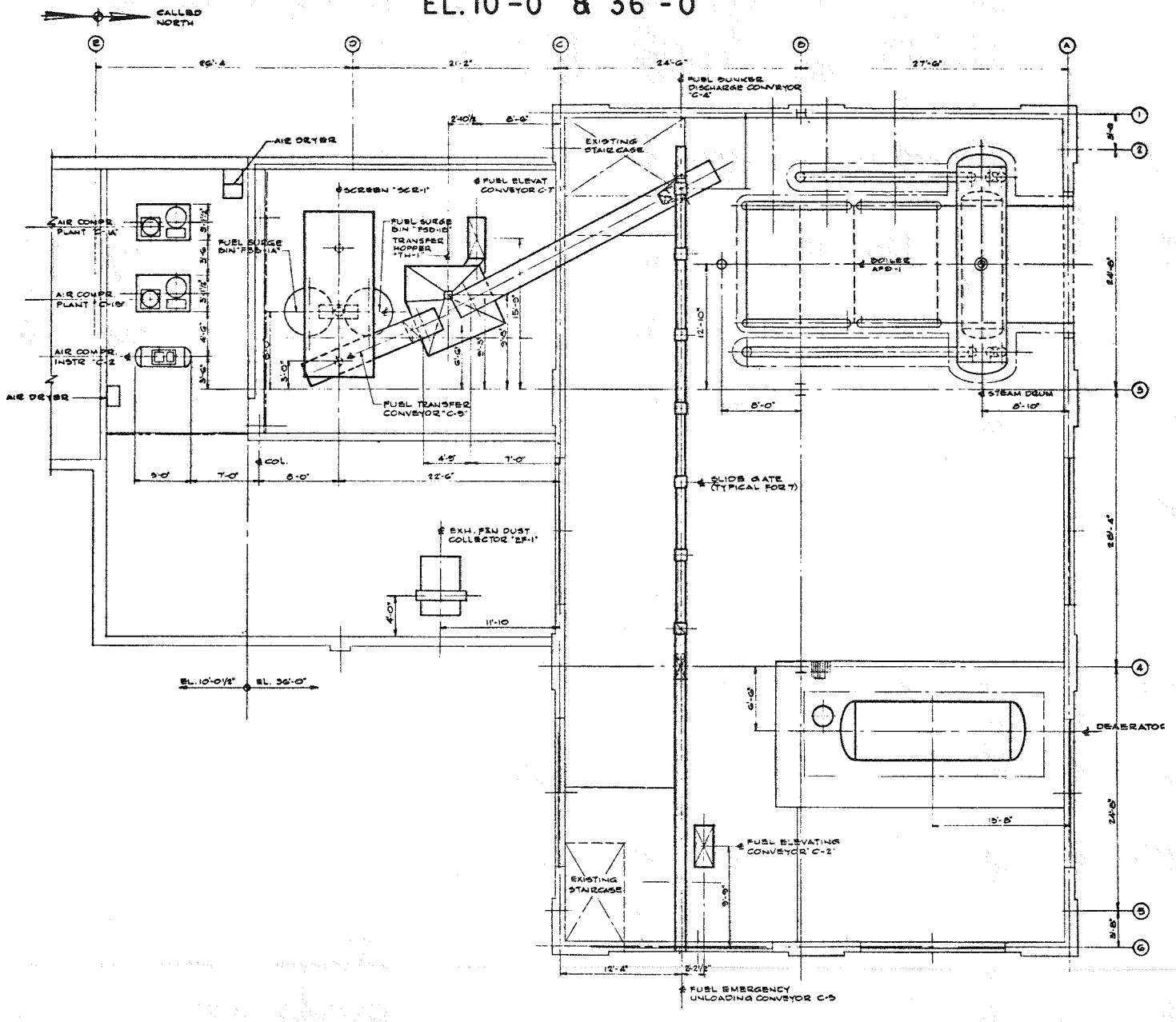


EXHIBIT 2-8B

MECHANICAL GENERAL ARRANGEMENT PLAN
EL. 60'-0"

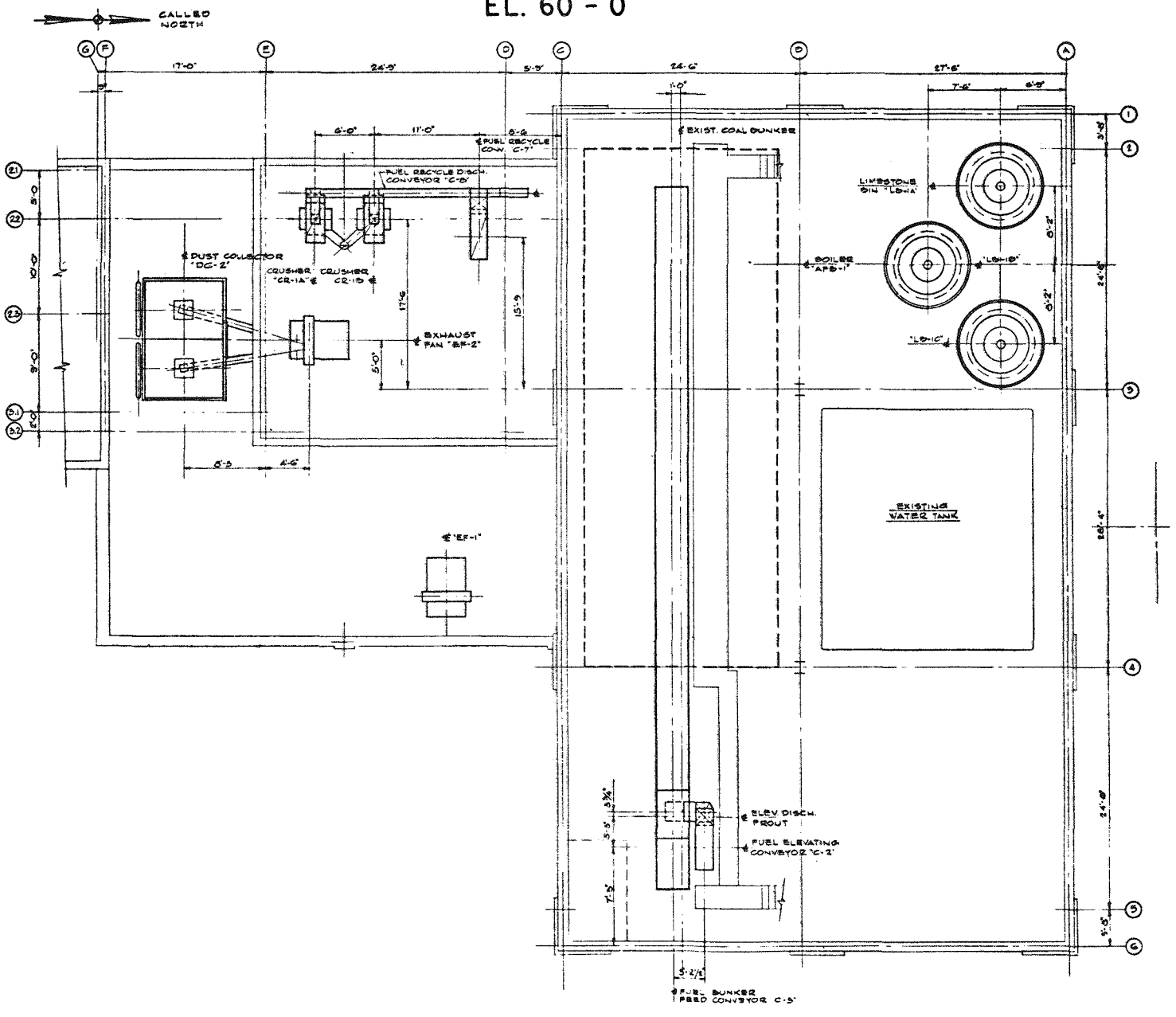
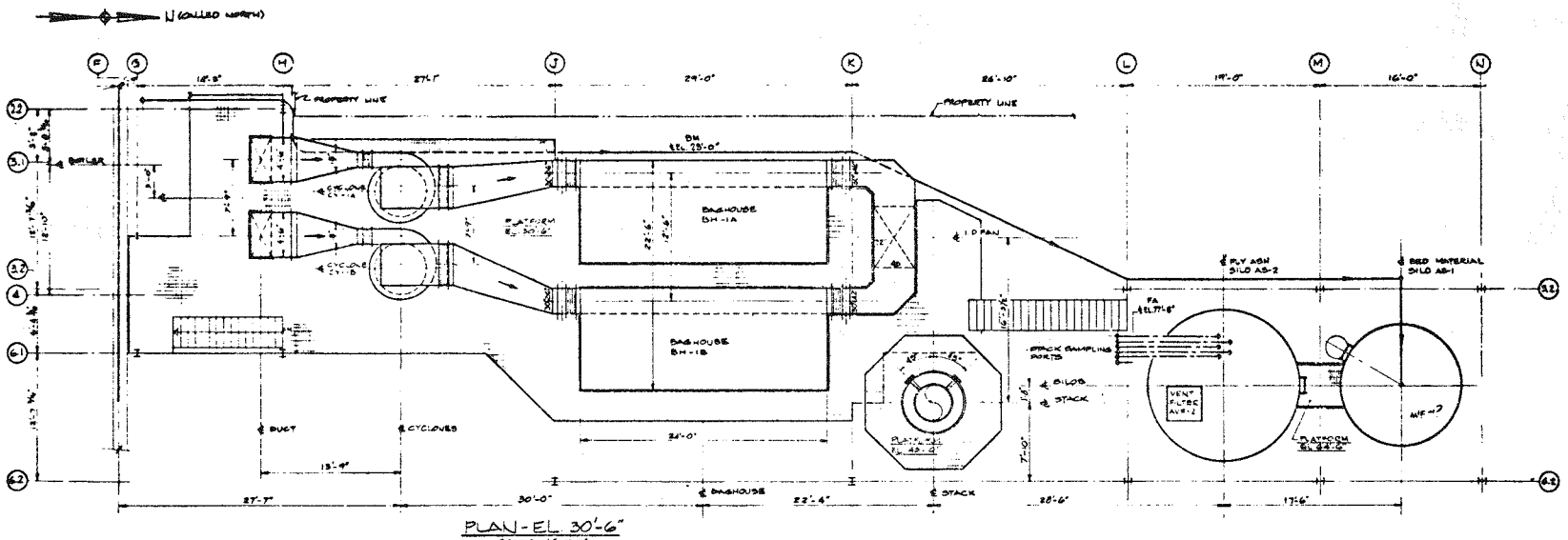
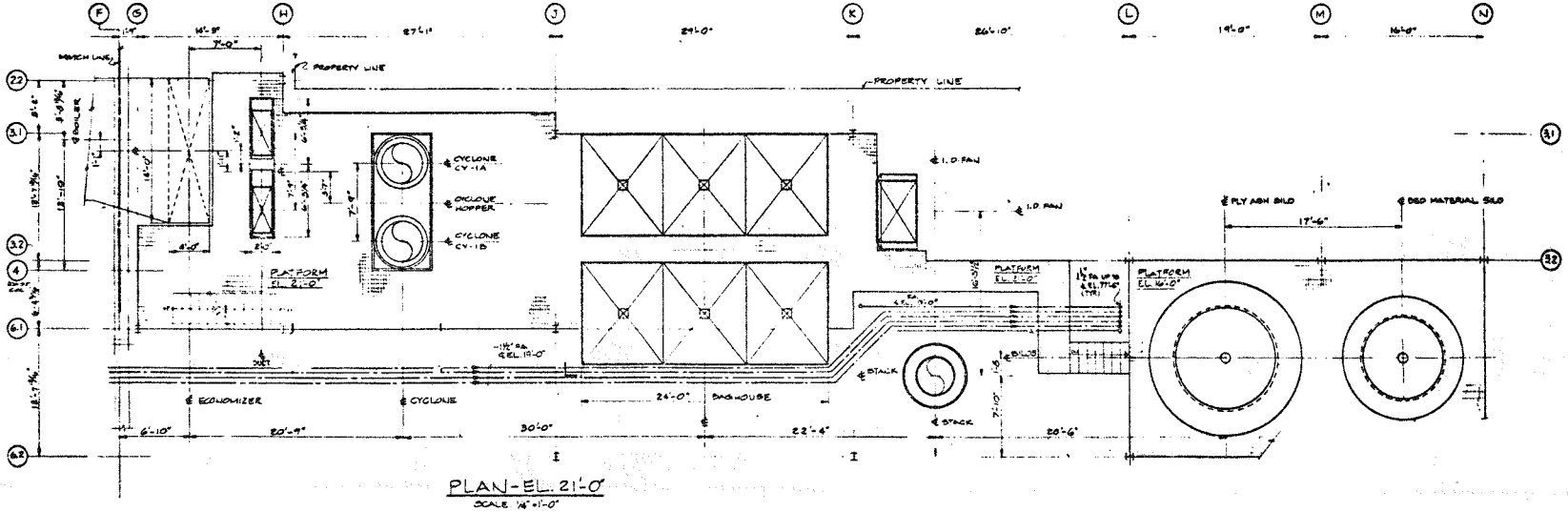


EXHIBIT 2-8C

MECHANICAL GENERAL ARRANGEMENT PLAN
EL. 21'-0" & 30'-6"



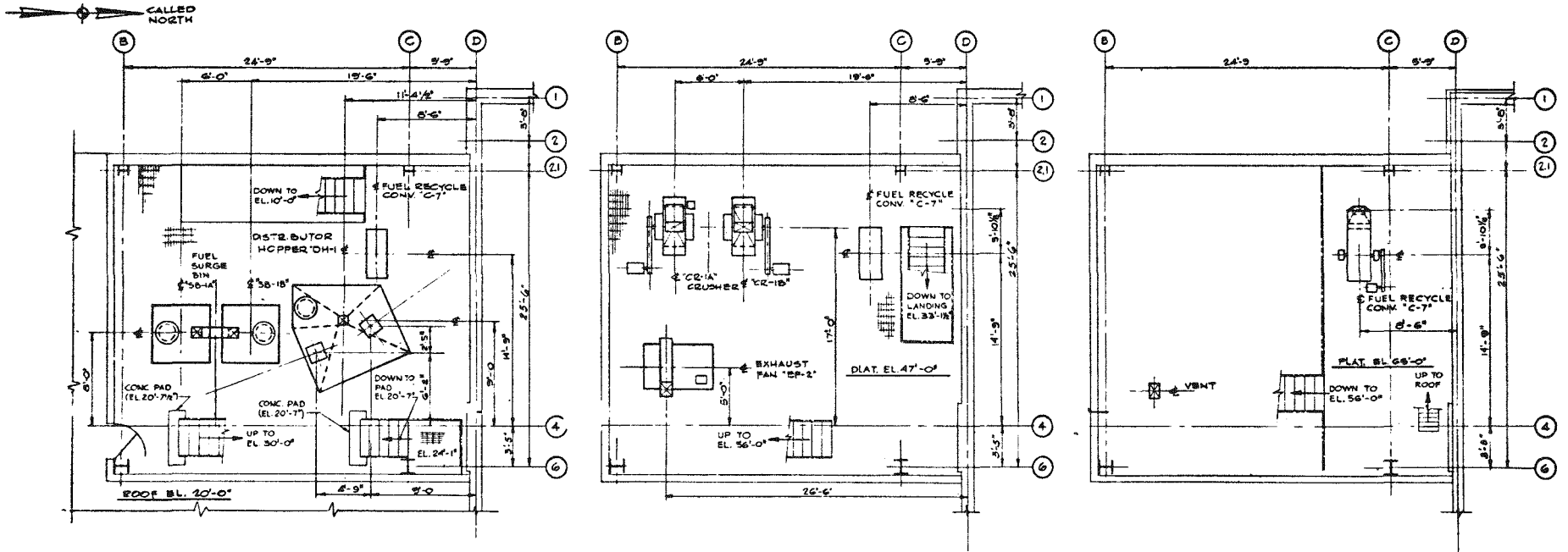
PLAN - EL 30'-6"
SCALE: 1/8" = 1'-0"



PLAN - EL. 21'-0"
SCALE 1/8" = 1'-0"

EXHIBIT 2-8D

MECHANICAL GENERAL ARRANGEMENT PLANS
FUEL PREPARATION AREA



PART PLAN
EL. 20'-0"
SCALE: 1/4" = 1'-0"

PART PLAN
EL. 47'-0"
SCALE: 1/4" = 1'-0"

PART PLAN
EL. 65'-0"
SCALE: 1/4" = 1'-0"

EXHIBIT 2-8E

POPE, EVANS AND ROBBINS

MECHANICAL GENERAL ARRANGEMENT
SECTION THRU EXISTING BOILER PLANT

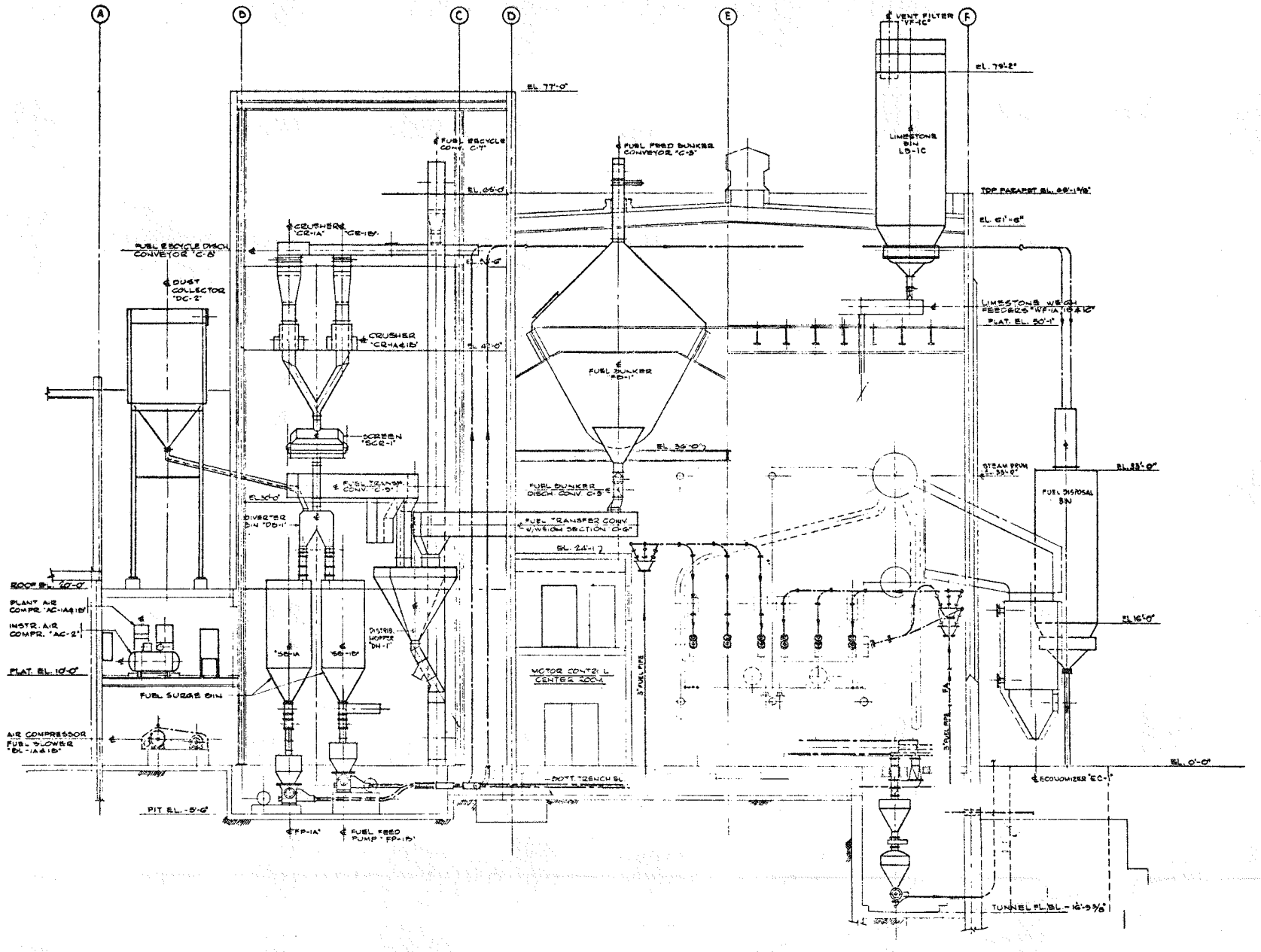


EXHIBIT 2-9A

MECHANICAL GENERAL ARRANGEMENT
SECTION THRU DUST COLLECTION AREA

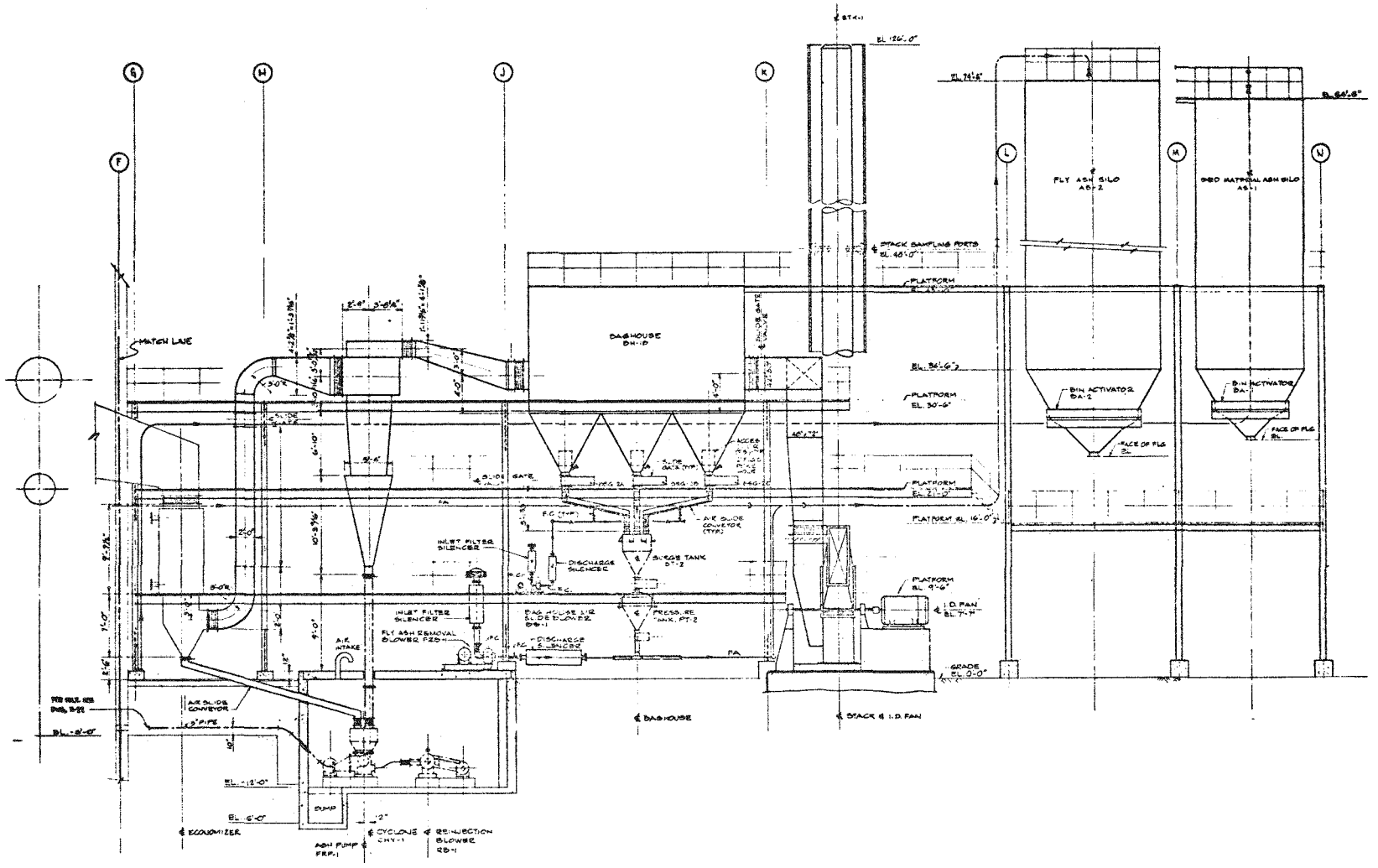
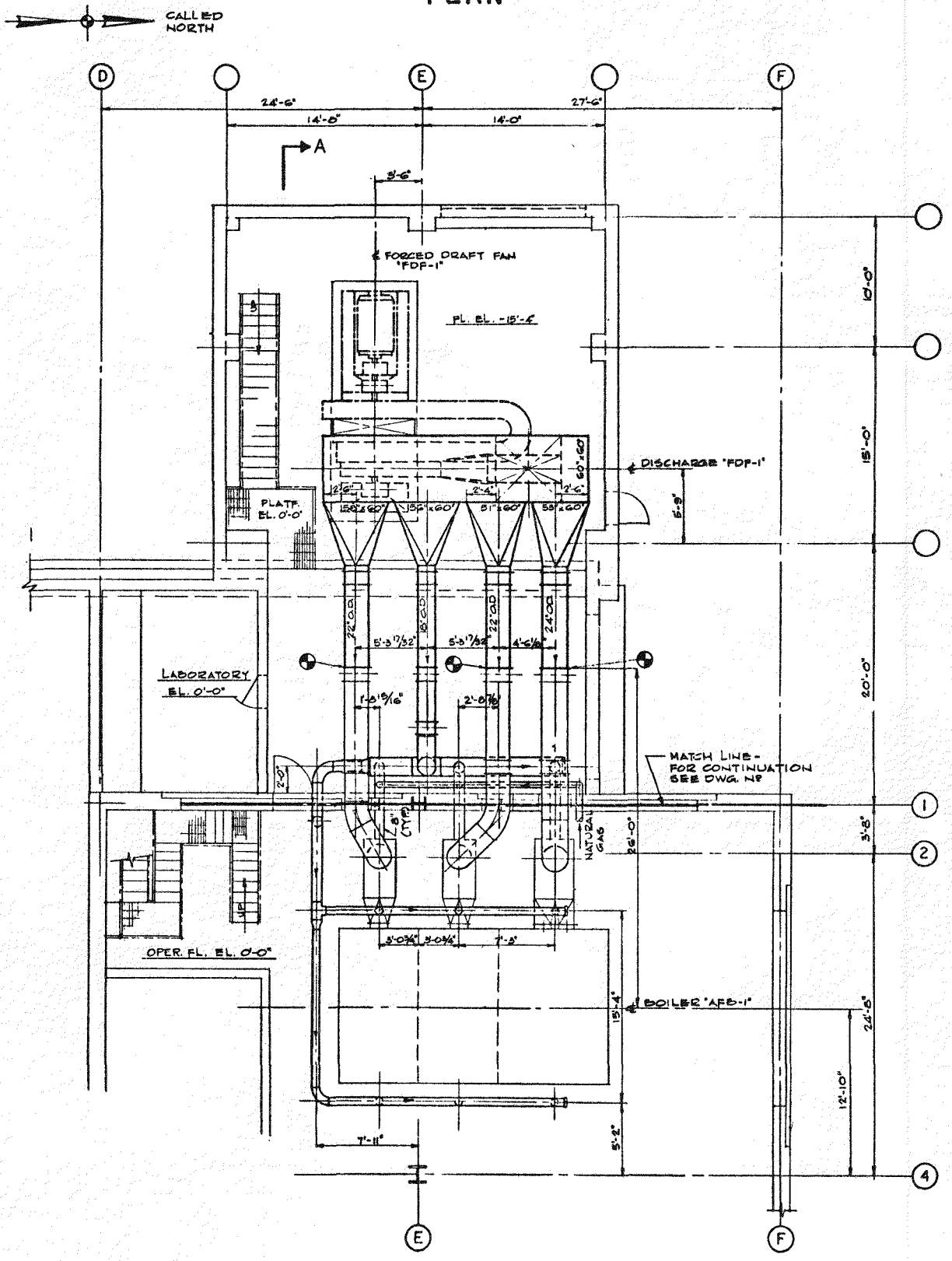


EXHIBIT 2-9B

MECHANICAL DUCT ARRANGEMENT TO FD FAN

PLAN



PLAN

MECHANICAL DUCT ARRANGEMENT TO FD FAN
SECTIONS

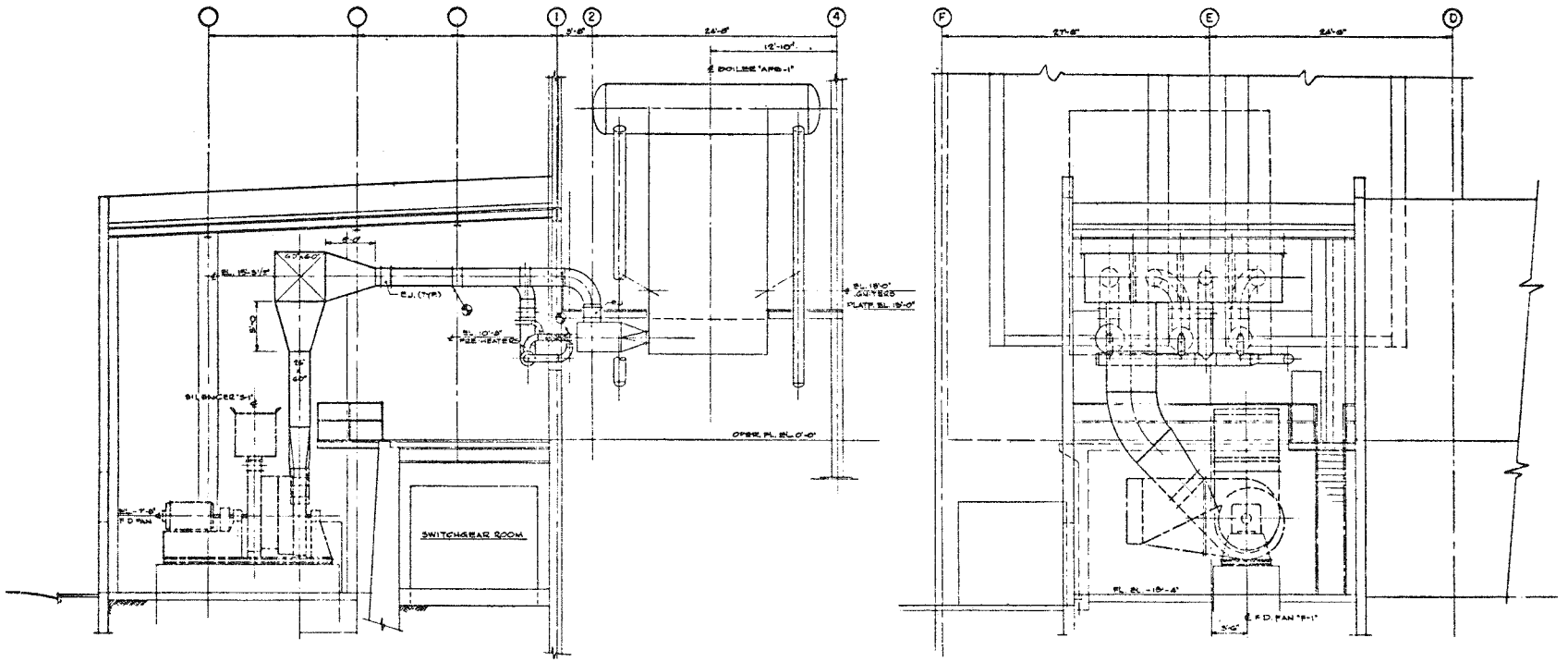


EXHIBIT 2-9D

POPE, EVANS AND ROBBINS

ELECTRICAL PRIMARY ONE-LINE DIAGRAM

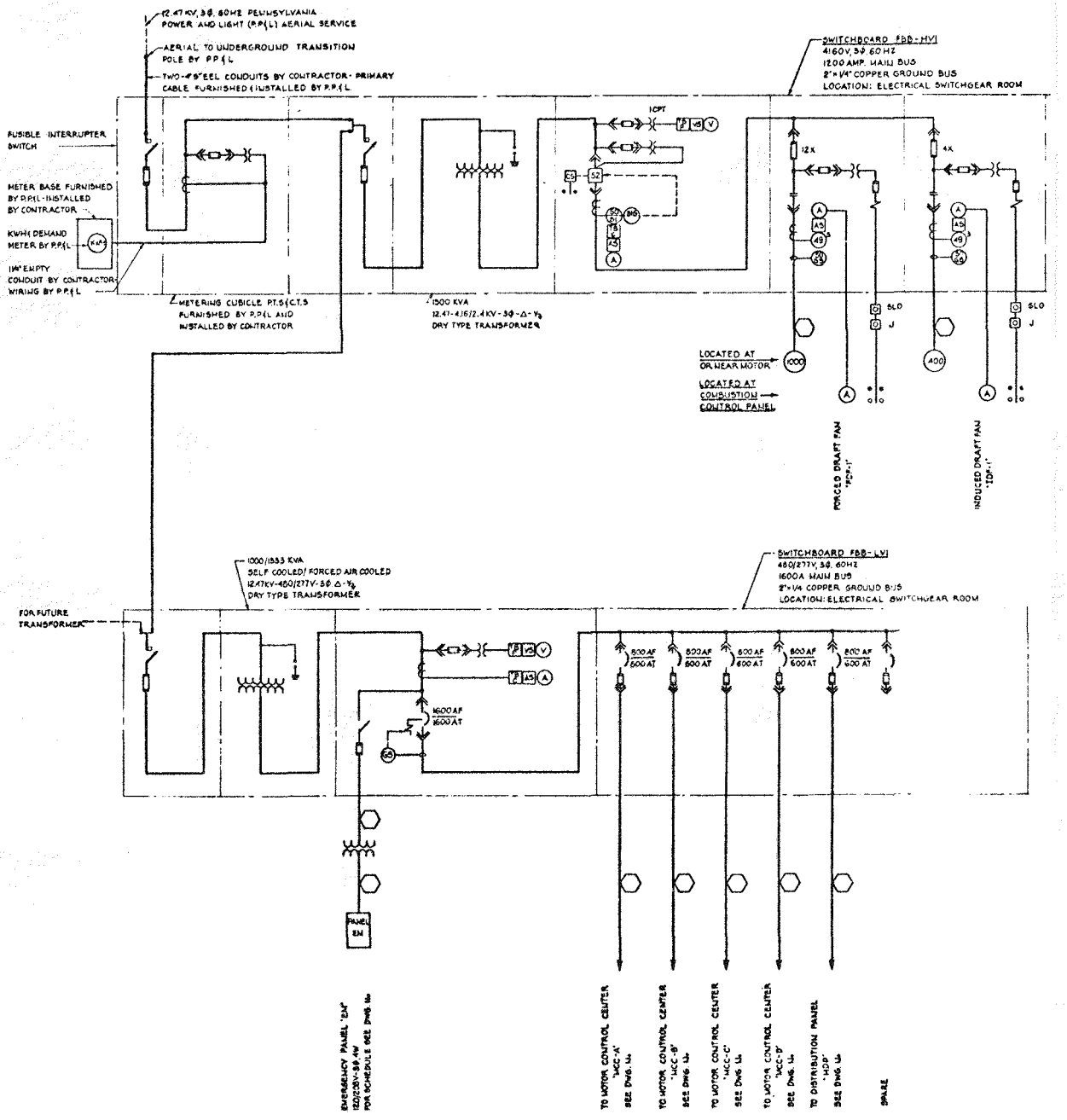


EXHIBIT 3-1A

ELECTRICAL 480 V ONE-LINE DIAGRAM SH. 1

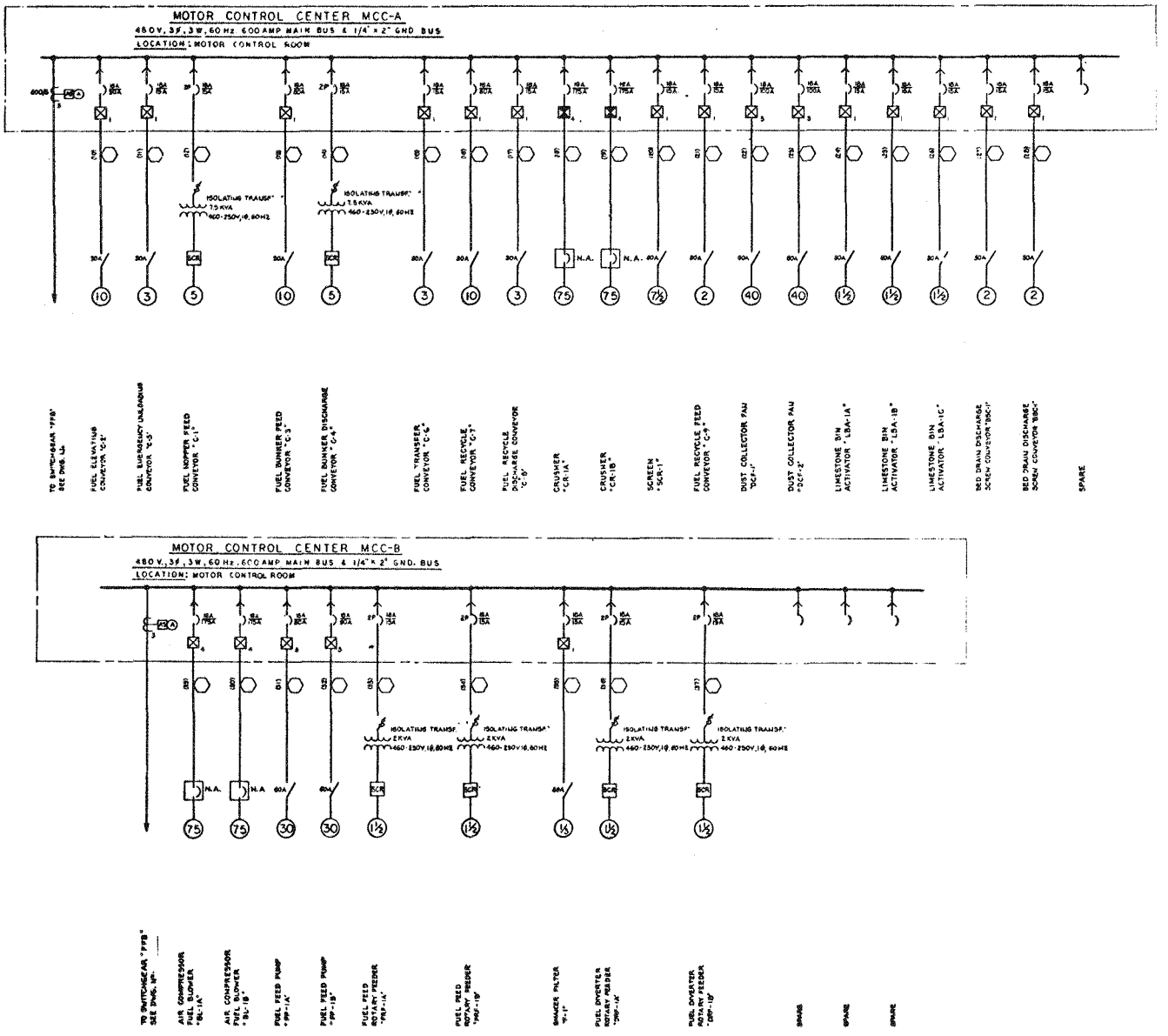


EXHIBIT 3-1B

POPE, EVANS AND ROBBINS

ELECTRICAL 480 V ONE-LINE DIAGRAM SH. 2

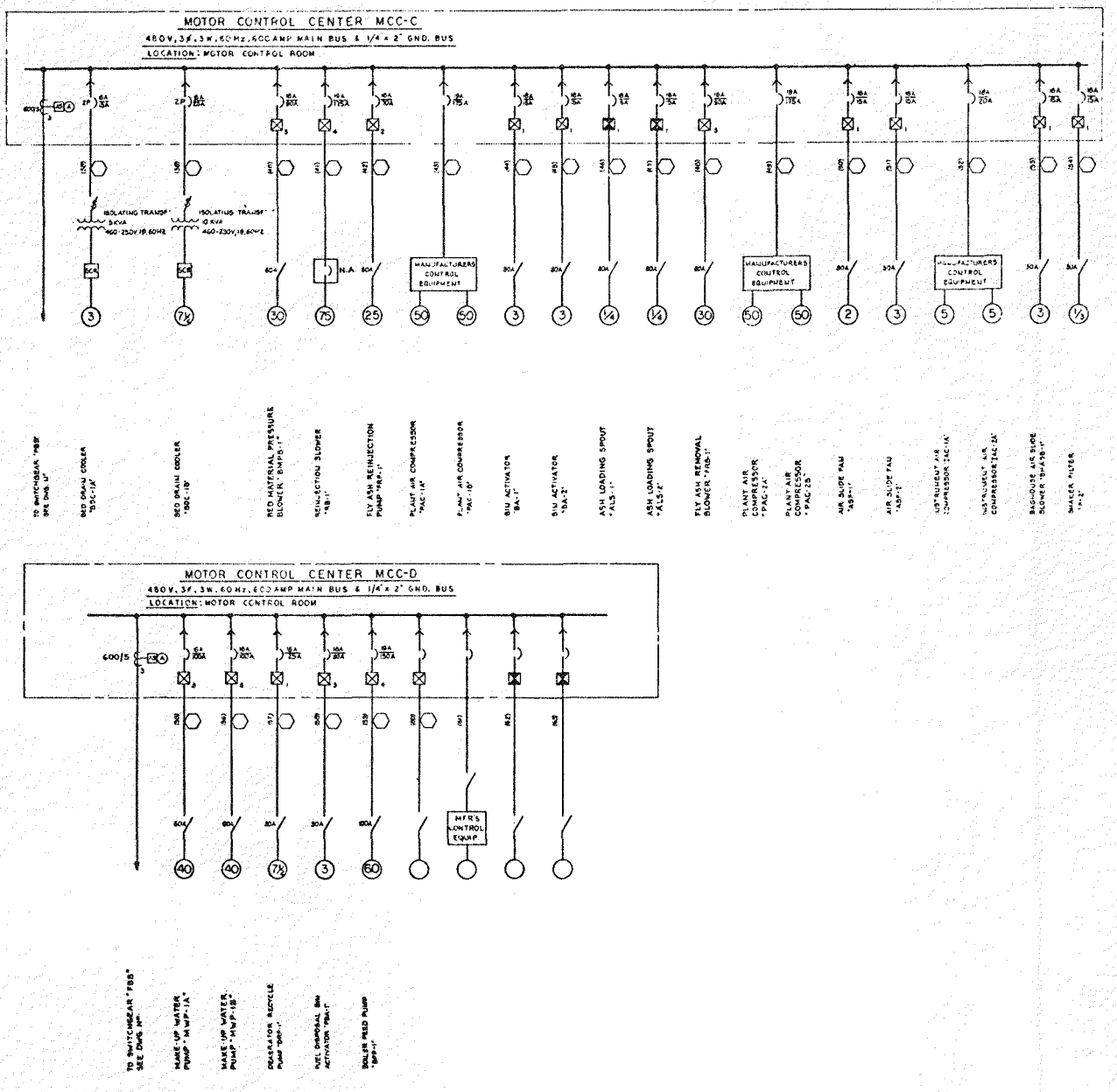


EXHIBIT 3-1C

STRUCTURAL FRAMING PLANS
DUST COLLECTION AREA

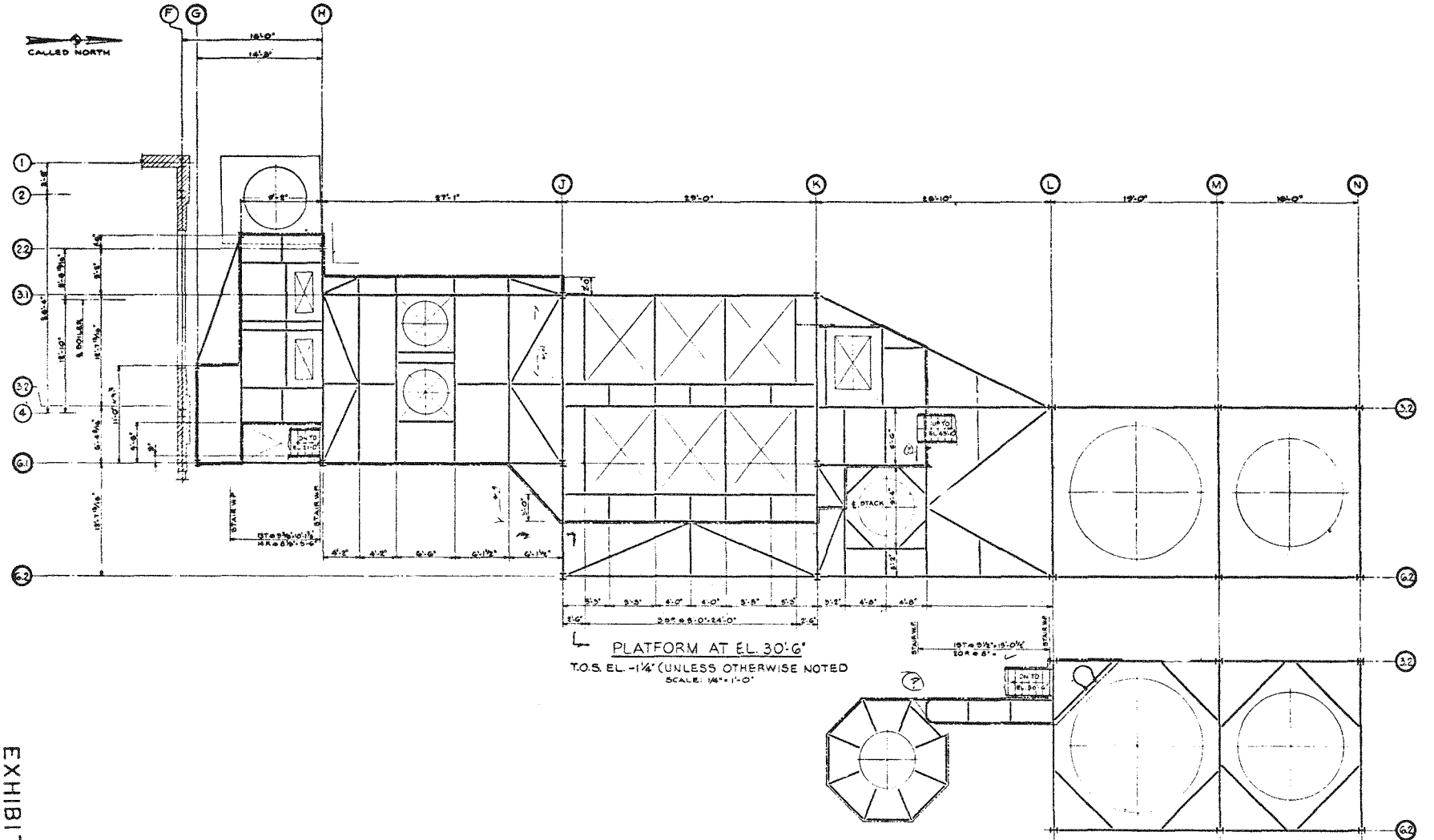
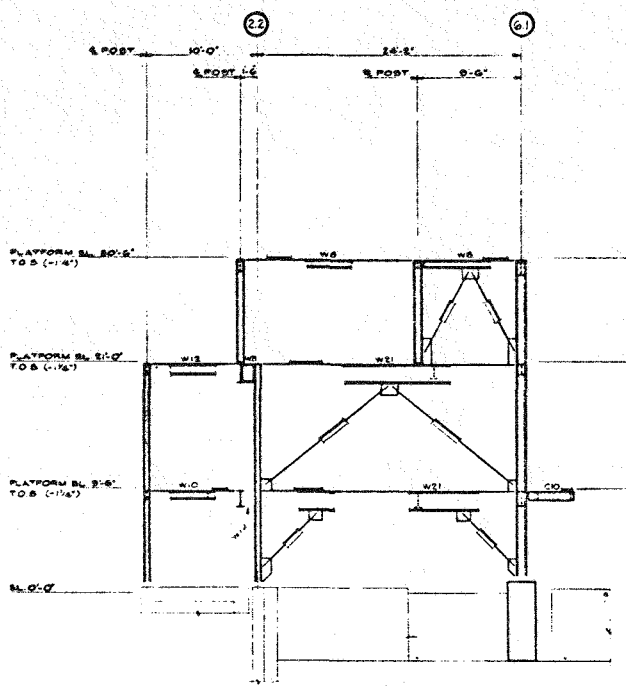
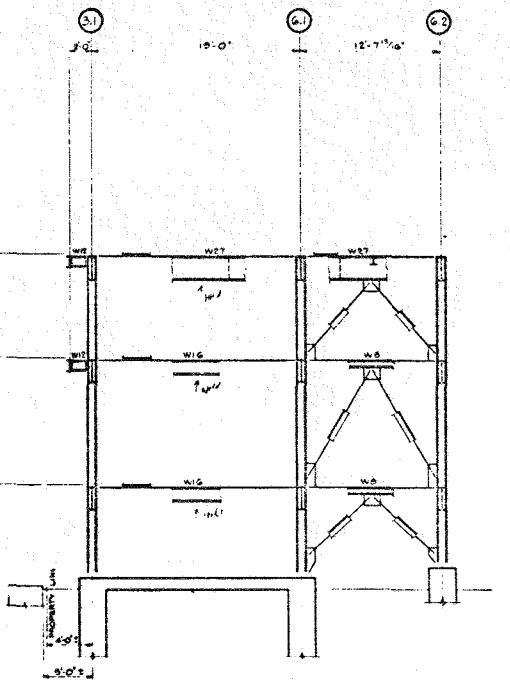


EXHIBIT 4-1A

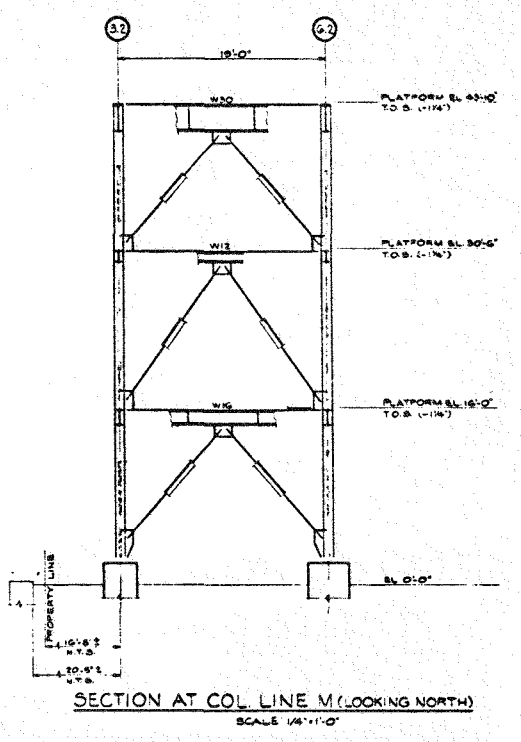
STRUCTURAL FRAMING SECTIONS
FUEL PREPARATION AREA



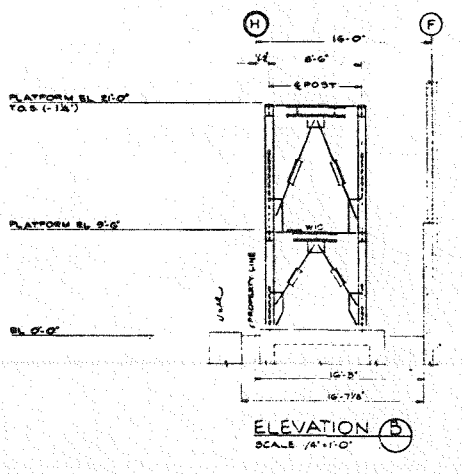
SECTION AT COL. LINE G (LOOKING NORTH)
SCALE 1/4"=1'-0"



SECTION AT COL. LINE J (LOOKING NORTH)
SCALE 1/4"=1'-0"



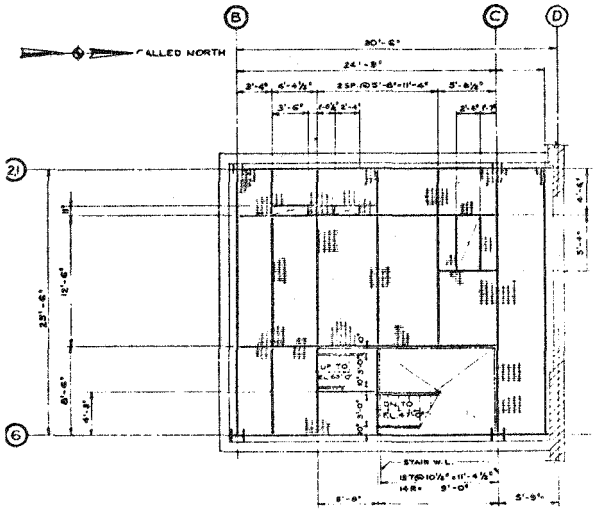
SECTION AT COL. LINE M (LOOKING NORTH)
SCALE 1/4"=1'-0"



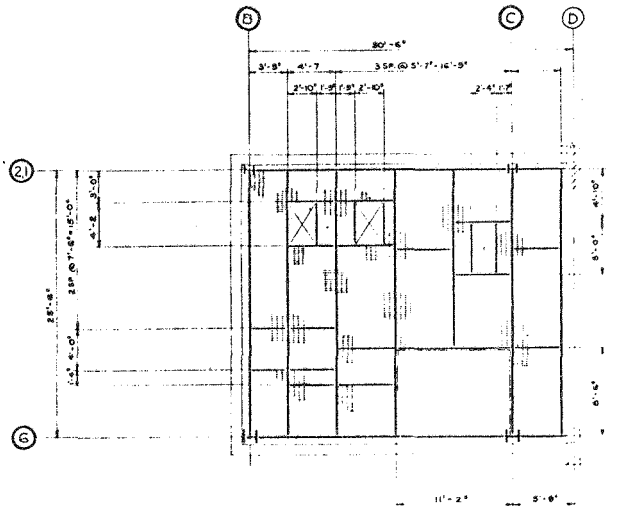
ELEVATION (5)
SCALE 1/4"=1'-0"

EXHIBIT 4-1B

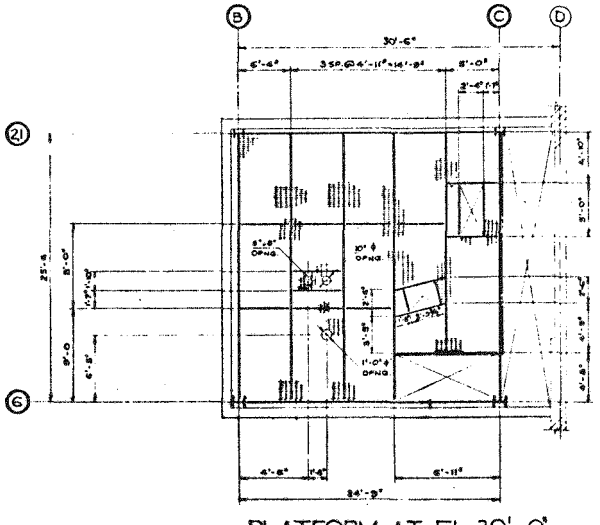
STRUCTURAL PLATFORM FRAIMING PLANS
FUEL PREPARATION AREA



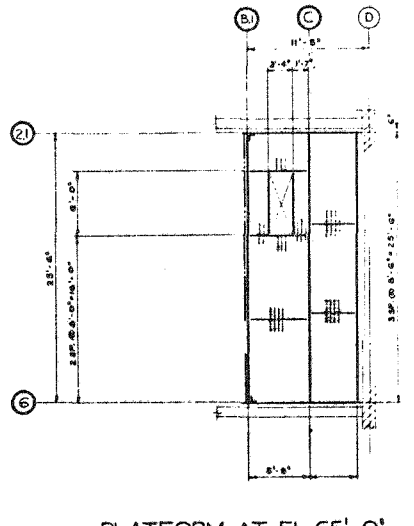
PLATFORM AT EL. 56'-0"
(T.O.S. EL. - 1¼" UNLESS OTHERWISE NOTED)
SCALE: 1/4" = 1'-0"



PLATFORM AT EL. 47'-0"
(T.O.S. EL. - 1¼" UNLESS OTHERWISE NOTED)
SCALE: 1/4" = 1'-0"



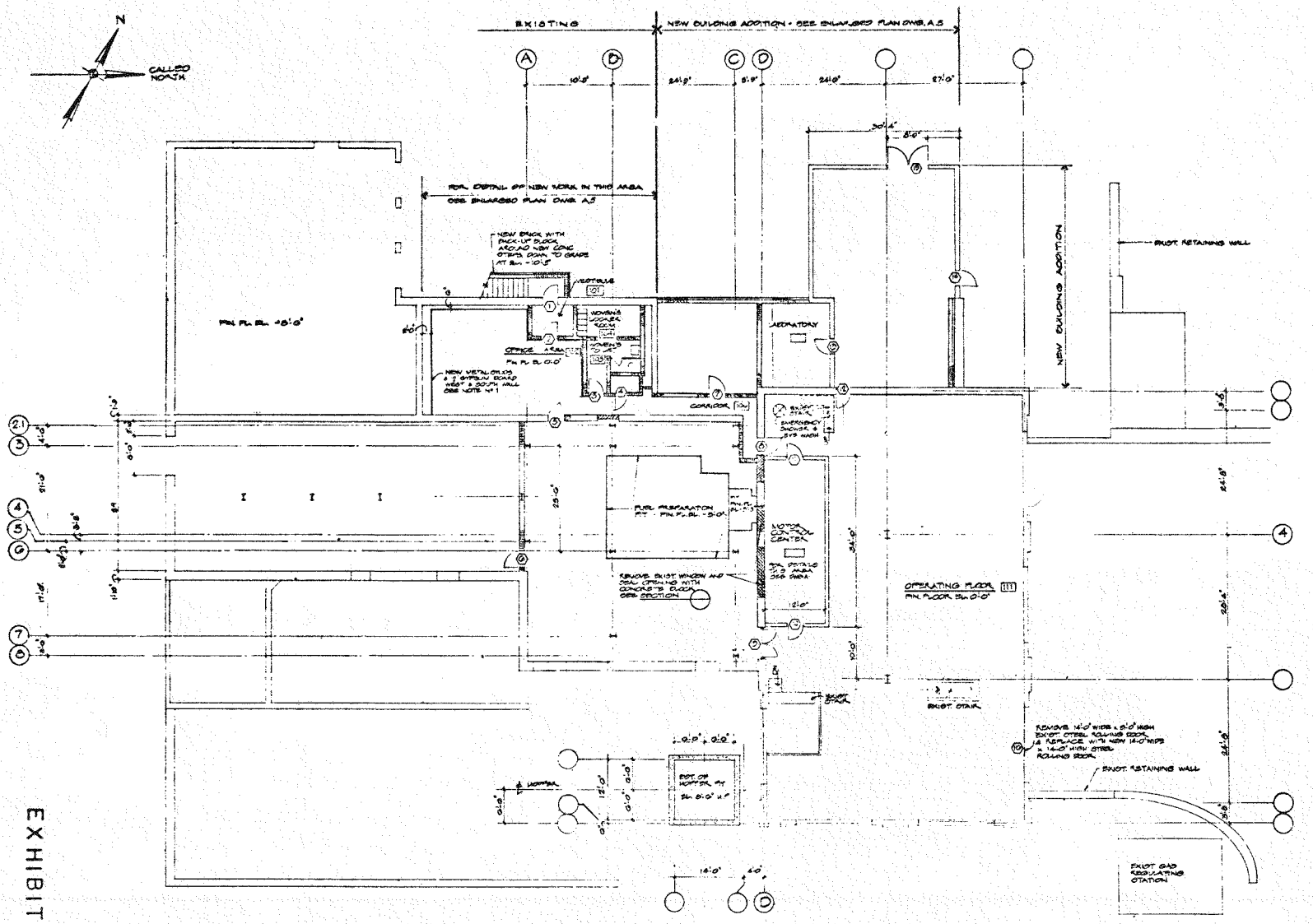
PLATFORM AT EL. 30'-0"
(T.O.S. EL. - 1¼" UNLESS OTHERWISE NOTED)
SCALE: 1/4" = 1'-0"



PLATFORM AT EL. 65'-0"
(T.O.S. EL. - 1¼" UNLESS OTHERWISE NOTED)
SCALE: 1/4" = 1'-0"

EXHIBIT 4-2A

ARCHITECTURAL - OPERATING FLOOR PLAN



NOTES

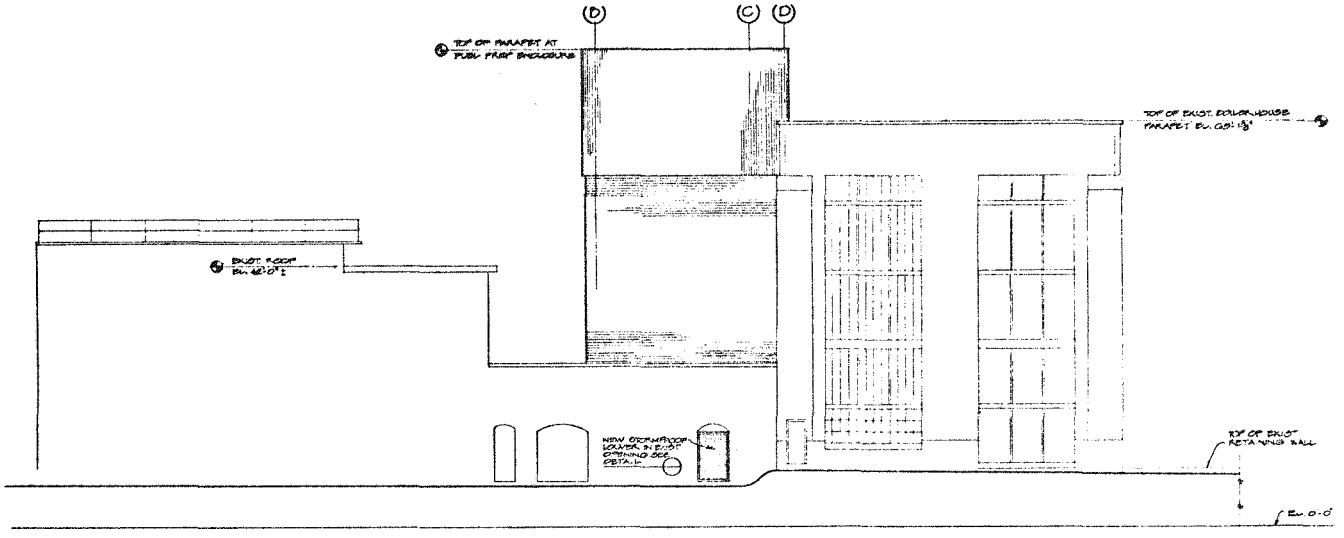
1. PROVIDE 3½" METAL STUD FRAMING 16" O.C. AT WEST & SOUTH WALL OF OFFICE [102] AT LOCATIONS SHOWN IN PLAN. STUD FRAMING REQUIRED IN LIEU OF WALL FURRING TO CORRECT IRREGULARITIES IN EXIST. BRICK WORK.

FLOOR PLAN

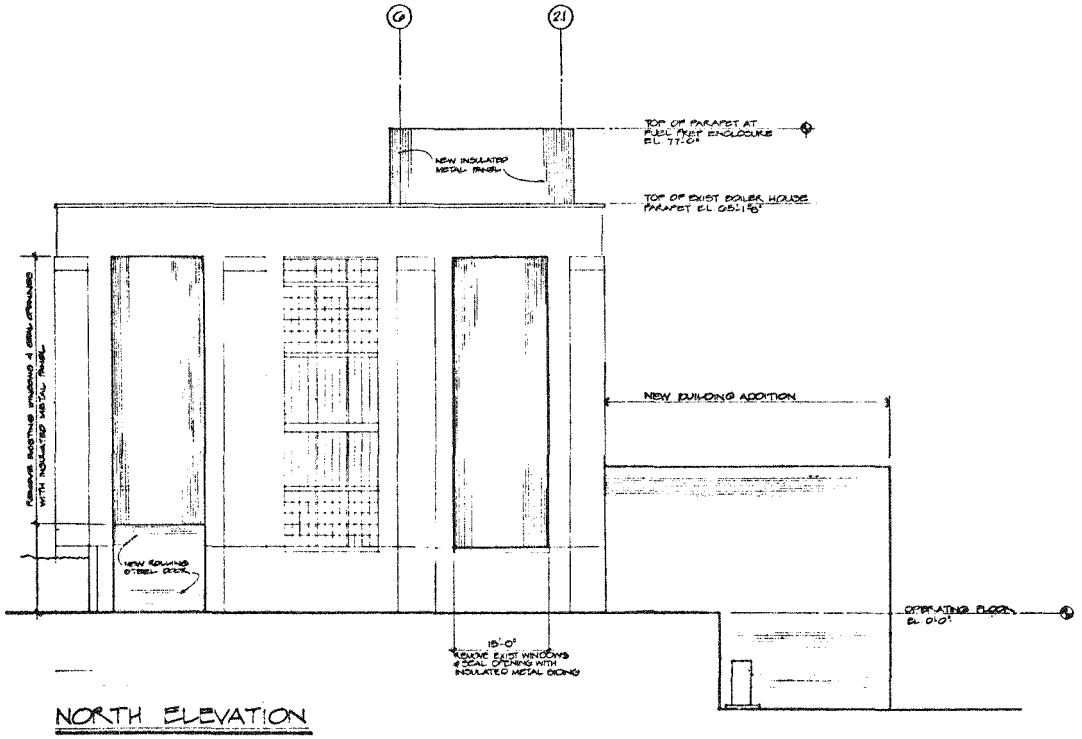
SCALE 1/8" = 1'-0"

EXHIBIT 5-1A

ARCHITECTURAL - NORTH AND EAST ELEVATIONS



EAST ELEVATION



NORTH ELEVATION

EXHIBIT 5-2A

EXISTING SITE CONDITIONS

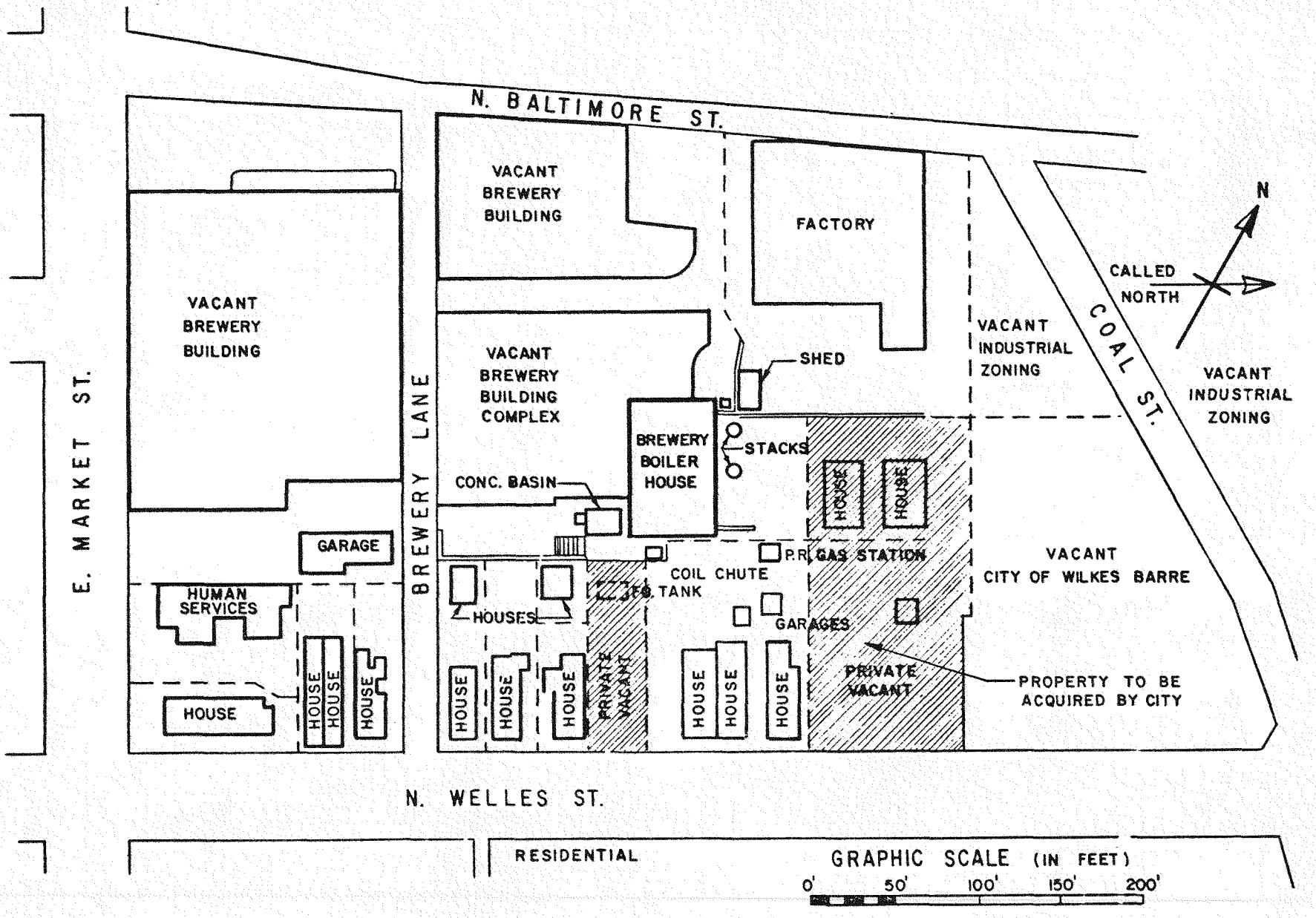


EXHIBIT 2-6

POPE, EVANS AND ROBBINS

NEW SITE CONDITIONS

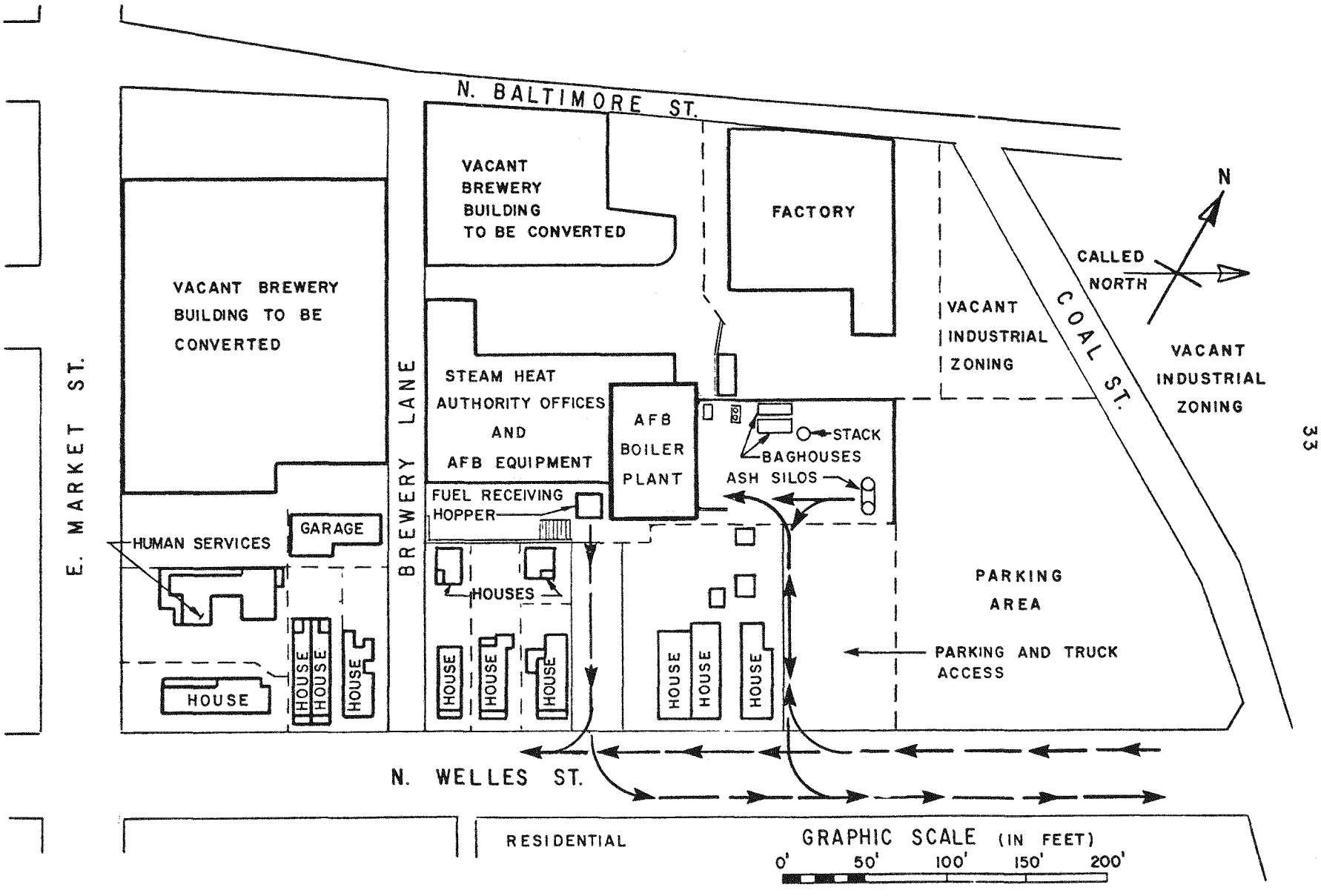


EXHIBIT 2-7

POPE, EVANS AND ROBBINS

WORK TO BE ACCOMPLISHED IN THE NEXT REPORTING PERIOD

A. Hot Model Testing

The Hot Model Test and Evaluation Report will be completed and issued.

B. Boiler Design

1. Work will continue on the boiler general arrangement drawings. The first issue of the "-20 series" general arrangement drawings will be completed.
2. Work will be completed on the design of the boiler pressure part circuitry and performance at full and partial loads.
3. Work will be initiated and completed on the computation of air and gas side pressure losses and F.D. & I.D. fan final sizing data.
4. Work will be initiated on writing the specifications for the following vendor supplied equipment:

   - Drum Safety Valves
   - Water Column & Gage Glass
   - Remote Level Indicator
   - Thermocouples
   - Feedwater Control Valve
   - Airflow Control Dampers
   - Miscellaneous Drain & Vent Valves
   - Pressure Port Purge System
   - Slide Gate Damper Actuators
   - Main Steam Stop & Check Valve
   - Air Measuring Devices

C. Final Design

1. Final plant design and bidding documents including drawings and specifications will be completed for General Construction, Mechanical and Electrical Contracts. Prepurchase equipment specifications will be completed and sent out for RFQ's.

D. Cost Estimate

Final Construction Cost Estimate and Program Costs will be completed.

E. Property Acquisition

The City of Wilkes-Barre will purchase required properties adjacent to the plant site required for access and construction.

F. Construction CPM

The Construction CPM will be revised to incorporate the latest design and construction approach.

G. Demolition

The City of Wilkes-Barre will continue its demolition program through the next report period.

DISCUSSION OF PROBLEM AREAS

A. Hot Model Testing and Boiler Design

1. Foster Wheeler evaluated the carbon combustion efficiency variation between the batch test results and the 100 hour verification test results discussed in the Monthly Status Report for July. It was determined that the long-term 100 hour verification test more accurately predicts the steady-state carbon combustion efficiency expected during normal operation. Based on this evaluation a carbon combustion efficiency of 82.0% (the corresponding fluidizing velocity was 8.0 ft./sec.) will be used in all further performance calculations in predicting overall boiler efficiency. All performance data issued will reflect the 82.0% value.

2. Early performance calculations were made based on a HHV as predicted by the Dulong formula. This was done because (a) there were no bomb calorimeter test results available at the time and (b) the Dulong formula is always within 1½% of the empirical HHV for bituminous, sub-bituminous and anthracite coals. Subsequent to this, bomb calorimeter tests were performed by various laboratory testing facilities to determine the HHV's. These HHV's were approximately 6% lower than those predicted by the Dulong formula. Based on these empirical results, it was decided to base unit design and material balance on a lower HHV of 5541 Btu/lb.

B. Final Plant Design

During this period the final mechanical design was brought to near completion. The results of the 100 hour verification test led Foster Wheeler to modify the boiler design. The boiler modification had the following impact on the plant design:

1. The plant arrangement and method of boiler support would have to be investigated for increased boiler size.
2. Increased flow requirements increased the size of the F.D. and I.D. fans.
3. Increase in power requirements led PER to revise the electrical service from a 440^{V} service to a $12,470^{V}$ service. Since Pennsylvania Power and Light Company would not supply a transformer for the higher voltage, transformers will have to be provided as part of this program.
4. Addition of three in-duct burners and six ignitors caused fit problems around the boiler and necessitated reworking of duct work to the F.D. fan and modification of F.D. fan enclosure.

Note: 1. The size of boiler was finally reduced to a point which would fit within the boiler plant and reduce support problems.

2. In October, Foster Wheeler will have revised the boiler to provide two cells in lieu of three cells and reduce the number of in-duct burners to two and the ignitors to four.

PROGRAM CONTROL

A. Schedule

1. Hot Model Testing

The Hot Model Test and Evaluation Report will be completed during the next report period.

2. Boiler Design

Although the start of final boiler design has been delayed due to evaluation of carbon burnup efficiency and HHV, the completion date for the final boiler design activity should not be affected.

3. Plant Design

The changes in boiler design has caused a two month delay in the schedule for completion of Phase I. Phase I which was to be completed by October 31, 1979, will probably be completed December 31, 1979.

B. Cost

1. The overall actual Foster Wheeler project costs through September 30, 1979 are currently within the budget estimate. The 30% cost estimate will be prepared and issued by November 5, 1979.

2. The cost impact of recent design changes is presently being evaluated. A new construction cost estimate and program estimate is being developed and will be available by November 5, 1979.

☆U.S. GOVERNMENT PRINTING OFFICE 1980-640-258/2483