MASTER

ENGINEERING EVALUATION
OF THE
PROPOSED BOILER ADDITION
FOR
MINNEGASCO ENERGY CENTER
Minneapolis, Minnesota

FINAL DRAFT REPORT

March 16, 1981

AMAF Industries Incorporated

DISCLAIMER

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Prepared for

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1.0 INTRODUCTION

This report presents the results of a technical evaluation of alternate fuels for the proposed oil and natural gas fired No. 3 boiler at the Minnegasco Energy Center (MEC) located in Minneapolis, Minnesota. This report has been prepared for the Department of Energy, Office of Fuels Conversion for their use in considering an alternate fuel exemption petition submitted by MEC.

This report presents the results of AMAF's evaluation of the MEC petition as well as information obtained during a site visit. The fuels considered for the proposed boiler include oil, natural gas, bituminous coal, petroleum coke/coal mixture, refuse-derived fuel (RDF), coal-oil mixtures, and coal/oil dual fuel fired. The purchase of steam from the Northern States Power Company was also considered as an alternative to construction of another boiler at MEC. AMAF's evaluation of each fuel included review of the overall plant design, estimates of capital and O&M costs, salvage value, useful life, and quantities of solid waste produced.

The MEC supplies steam and chilled water to the downtown Minneapolis area for building heating and cooling. The MEC presently owns and operates two 200,000 lb/hr oil/natural gas fired boilers which supply steam for heating or operation of the chilled water system equipment. If the proposed boiler is permitted to burn oil and natural gas, it will be identical in design to the existing boilers.

2.0 SUMMARY

Based on AMAF's evaluation of the MEC petition and site visit, the use of oil, natural gas, coal, petroleum coke-coal mixtures, coal-oil mixtures, and coal/oil dual fuel firing appear technically feasible as fuel choices for the proposed boiler. The purchase of steam from the Northern States Power Company appears feasible as an alternative to the installation of a new boiler at the MEC.

Offsite storage space would be required for receiving and storing coal, petroleum coke, or RDF. Offsite fuel preparation facilities are required for preparing petroleum coke-coal mixtures and RDF.

3.0 TECHNICAL EVALUATION

3.1 Alternate Fuel Availability

The proposed plant design for installation of Boiler No. 3 at MEC is based on the use of residual oil or natural gas. Alternate fuels considered for use at the MEC instead of oil or gas include bituminous coal, petroleum coke/coal mixture, refuse derived fuel (RDF), coal-oil mixtures (COM) and dual fuel firing capability with coal and oil. There are fuel suppliers capable of supplying any of the alternate fuels considered for this project except for RDF. Availability of alternate fuels has been confirmed with the following companies:

Fuel	Supplier
Bituminous coal	Great Lakes Coal & Dock Co.
Petroleum coke/coal	coke: Koch Carbon, Inc. coal: Great Lakes Coal & Dock Co.
Coal-oil mixtures	CoaLiquid, Inc.

The use of RDF would require construction of an offsite preparation facility by MEC or the purchase of fuel from a source outside of the Twin Cities area. Although there is some local government interested in developing RDF as a boiler fuel, consideration to date has been limited to the use of RDF at Northern States Power Company's Riverside Plant.

3.2 Space Requirements

The MEC was designed to permit installation of three additional oil/gas fired boilers similar to the two existing boilers. Although designed to accommodate oil and gas fired boilers, the MEC could accommodate one boiler designed to burn any of the alternate fuels discussed in Section 3.1 with limited onsite fuel storage. The existing building roof located directly above the boilers would have to be removed and replaced with a new roof located 44 feet higher than the old roof.

Additional building space at MEC would be required to house the precipitator or baghouse and the coal unloading facilities. There is adequate space to locate the precipitator or baghouse along the north wall of the existing building. There is adequate space along the east wall of the existing building for coal unloading facilities. Simplified arrangment drawings of the equipment required for using the base and alternative fuels evaluated in this report are presented in appendix C.

Offsite storage space in the metropolitan area would be required for receiving and storing coal, petroleum coke or RDF. Fuel preparation operations for petroleum coke and RDF would also be performed at these offsite locations.

Coal will be received at the site in 20 ton trucks. Based on a coal fuel heat content of 12,000 Btu per pound and weekday deliveries, 17 trucks per day would be received at the site. The use of lower heat content fuels would increase the number of deliveries required.

The time required for a complete delivery cycle is dependent on the distance between MEC and the truck loading point. Assuming the distance between MEC and the truck loading point is 5 miles, about 1-1/2 hours would be required per trip. The delivery cycle requires 10 minutes for loading the truck, 30 minutes for travel to MEC, 10 minutes to unload the truck, and 30 minutes to return to the truck loading area.

When a truck arrives at MEC, the coal will be dumped into a hopper in the coal handling building. The coal will be transported between the hopper and the coal storage bunker by conveyors. Coal would be discharged from the bunker to coal feeders which feed coal to the stoker grates.

If a fuel other than oil or natural gas is used in the proposed boiler, an offsite ash disposal area will be required. Annual ash production rates for each fuel are summarized in table 3.8. Ash will be collected from the boiler and hopper and the baghouse or precipitator ash hoppers by a pneumatic ash handling system and conveyed to a storage bin where it will be held for removal from the site. The storage bin should have sufficient capacity to hold all of the ash produced during 64 hours of operation at full load. Trucks will be used to transport ash to an offsite disposal area.

The time required for a complete delivery cycle is dependent on the distance between MEC and the disposal site. Assuming the distance between MEC and the offsite facility is 5 miles, about 1-1/2 hours would be required per trip. One trip per day would be required if coal is fired; 6 trips per day would be required if RDF is fired. The delivery cycle requires 10 minutes for loading the truck, 30 minutes for travel to the disposal area, 10 minutes to unload the truck, and 30 minutes to return to MEC.

3.3 Equipment Requirements

Design conditions the major equipment required for each of the base and alternative fuels are summarized in tables 3-1 to 3-7. Except for the purchase of steam from NSP, the major equipment required for this project includes:

1. boiler.
2. a new stack and extensions to existing stacks.
3. interconnecting piping between the new boiler and the existing condensate and steam systems.
4. ductwork between the boiler and stack.

5. boiler feed pumps.
6. emission control equipment.
7. fuel handling equipment.
8. ash handling equipment for solid fuels.

Design of the boiler, emission control equipment, fuel and ash handling equipment is determined by the fuel selected for use. The overall dimensions of the boiler are the most important boiler design item influenced by fuel selection.

The purchase of steam from the Northern States Power Company would be an alternative option to the installation of the proposed boiler at the MEC. If steam was purchased from NSP, a steam supply line and a condensate return line would be required to connect the existing MEC system to NSP's Riverside Plant.

TABLE 3-1
ENGINEERING DESIGN SPECIFICATION
OF EQUIPMENT FOR OIL/GAS FIRED BOILER

1. Boiler

Shop assembled water tube package boiler with design capacity of 200,000 lb/hr saturated steam at 250 psig; boiler efficiency is 86 percent; boiler includes instrumentation, controls and access platforms. The following major equipment will be included in the boiler manufacturer's scope of supply:

a. forced draft fan and drive.
b. mechanical dust collector.
c. air heater.
d. sootblowers.

2. Stacks

			Existing	New
Number:			2	1
Height above grade:			110 ft.	160 ft.
Exit diameter:			4.92 ft.	4.92 ft.
Flue gas:	Exit velocity	with oil firing	61.7 ft./sec.	61.7 ft./sec.
	Exit volume rate	with oil firing	70,390 ACFM	70,390 ACFM
	Exit temperature	with oil firing	301°F	301°F

Existing stacks will be extended to 160 ft.

TABLE 3-1 (cont'd)

3. Piping

Extensions to existing system. The following sizes are assumed for discussion purposes:

a. condensate return - 4" pipe with insulation.

b. steam - 12" pipe with insulation.

c. to deaerator - 2-1/2" pipe with insulation.

(See appendix A for calculations).

4. Ductwork

6' X 6' insulated steel ductwork boiler, fan, and stack.

5. Boiler Feed Pumps

Two multistage horizontal centrifugal pumps rated 400 gallons per minute at 300 psi with electric motor drives.

TABLE 3-2
EQUIPMENT DESIGN SPECIFICATION
OF EQUIPMENT FOR COAL-FIRED BOILER

1. Boiler

Ship assembled water tube boiler fitted with a traveling grate spreader stoker, design capacity 200,000 lb/hr saturated steam at 250 psig; boiler efficiency is 84 percent; boiler includes instrumentation, controls, and access platforms. The boiler would be designed to fire eastern Kentucky bituminous coal with a heat content of 13,710 Btu/lb. The following standard components will be included in the boiler manufacturer's scope of supply:

a. forced draft and induced draft fans and drives.

b. continuous ash discharge stoker.

c. air preheaters and heaters.

d. soot blowers.

e. connecting duct work and insulation.

2. Coal Handing Equipment

Coal unloading and handling system includes the following major equipment:

a. truck hopper with grating overall size 14' X 32'.

b. 20" inclined belt feeder with 3 hp motor.

c. 24' belt conveyor inclined with 3 hp motor.

d. 94' center-to-center bucket elevator with 25 hp motor.

e. 120; belt conveyor with 5 hp motor.

TABLE 3-2 (cont'd)

f. 30' belt conveyor with 3 hp motor, complete with a trigger conveyor having a 2 hp motor.

g. bunker to stoker equipment which would be complete with two gates, scales, and conical distributors. The scales would have 3/4 hp motors.

h. Control panel to contain the necessary lights, switches, etc., for the system.

3. Ash Handling Equipment

Pneumatic ash handling system includes the following major components:

a. 14' X 28' bin with no enclosure to be erected inside the existing building.

b. four-door bottom ash hopper and 8" piping to bin.

c. 6" economizer branch piping.

d. 6" air heater branch piping.

e. six inch baghouse branch piping.

f. bag filter.

g. bag filter controls.

h. two vacuum pumps.

i. silo unloading equipment.

j. main control package.

TABLE 3-2 (cont'd)

4. Air Pollution Control Equipment

Air pollution control equipment includes a baghouse with an efficiency of 99+ percent and an air/cloth ratio of 3.15.

5. Mechanical Collector

A mechanical collector with an efficiency of 70-80 percent for precleaner to baghouse. Scope of supply includes tubes, structural steel, insulation, and equipment installation.

6. Stacks

		Existing	New
Number:		2	1
Height above grade:		110 ft.	160 ft.
Exit diameter:		4.92 ft.	5.86 ft.*
Flue gas:	Exit velocity	61.7 ft./sec.	61.7 ft./sec.
	Exit volume rate	70,390 ACFM	100,000 ACFM
	Exit temperature	301°F	301°F

Existing stacks will be extended to 160 feet.

7. Offsite coal pile storage is required. For 90 days reserve of coal about 1.7 acres of land would be required to provide a coal pile 15 feet high. (See appendix for calculation).

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* See appendix A for calculation.

TABLE 3-2 (cont'd)

8. Existing plant equipment

Relocation of deaerator and water treating equipment is required to install the boiler.

9. Boiler feed pumps

Two multistage horizontal centrifugal pumps rated 400 gallons per minutc at 300 psi with electric motor drives.

TABLE 3-3
ENGINEERING DESIGN SPECIFICATION
OF EQUIPMENT FOR COAL-FIRED BOILER
USING PETROLEUM COKE MIXTURE

1. Boiler

The boiler is similar to the standard coal-fired boiler plant. This boiler will burn 30 percent petroleum coke and 70 percent Montana coal and has a boiler efficiency of 82 percent.

2. Air Pollution Control Equipment

A baghouse would be used for particulate control. Equipment design would be identical to that required for the coal fired alternate.

3. Fuel Storage

Offsite coal pile storage is required for the coal-fired boiler using petroleum coke mixture. For 90 days reserve of petroleum coke and coal about 1.4 acres of land is required for a coal storage pile 15 feet high. (See appendix for calculation).

4. Existing Plant Equipment

Relocation of deaerator and water treating equipment is required to install coal-fired boiler using petroleum coke mixture as fuel.

5. Boiler Feed Pumps

Two multistage horizontal centrifugal pumps rated 400 gallons per minute at 300 psi with electric motor drives.

TABLE 3-4

ENGINEERING DESIGN SPECIFICATION OF EQUIPMENT FOR STOKER-FIRED BOILER FIRING REFUSE-DERIVED FUEL (RDF)

1. Boiler

The boiler is identical to a boiler using standard coal except that it requires different materials of construction for satisfactory operation with RDF. The fuel used is prepared RDF from a municipal refuse process plant. The boiler efficiency is 75 percent.

2. Electrostatic Precipitators

The precipitator has an efficiency of 98.0 percent; flue gas velocity 3.31 feet/sec and collecting plate area of 36,288 square feet. The precipitator will include the following components:

a. inlet and outlet nozzles.

b. weather enclosure.

c. insulation.

d. walkways and stairtower.

e. structural steel.

3. Existing Plant Equipment

Relocation of deaerator and water treating equipment is required to install the boiler.

4. Boiler Feed Pumps

Two multistage horizontal centrifugal pumps rated 400 gallons per minute at 300 psi with electric motor drives.

TABLE 3-4 (cont'd)

5. Ash Handling System

An ash handling system similar to the system described for the coal fired plant is required. The system would handle ash collected by the boiler and precipitator.

TABLE 3-5
ENGINEERING DESIGN SPECIFICATION OF EQUIPMENT FOR BOILER FIRING COAL-OIL MIXTURE (COM)

1. Boiler

The boiler is a standard design, pulverized coal fired water tube boiler with burners modified for COM. The fuel will be a mix of 60 percent No. 6 fuel oil and 40 percent pulverized eastern Kentucky bituminous coal. The boiler has an efficiency of 85 percent.

2. Fuel Storage

One of the existing oil storage tanks would be used for COM storage.

3. Air Pollution Control Equipment

For air pollution control equipment, the use of an electrostatic precipitator similar to the one specified for the RDF fired boiler is required.

4. Fuel Mixing Plant

A mixing plant for COM is not required. Fuel can be purchased pre-mixed.

5. Ash Handling System

An ash handling system similar to the system described for the coal fired plant is required. System would handle ash collected by boiler and precipitator.

TABLE 3-5 (cont'd)

6. Existing Plant Equipment

Relocation of deaerator and water treating equipment is required to install the boiler.

7. Boiler Feed Pumps

Two multistage horizontal centrifugal pumps rated 400 gallons per minute at 300 psi with electric motor drives.

TABLE 3-6
ENGINEERING DESIGN SPECIFICATION
OF EQUIPMENT FOR STEAM SUPPLY BY UTILITY COMPANY

1. A pressure reducing valve station and a desuperheater are required to provide 300 psi, 460^{o} steam to MEC.

2. Underground piping between the Riverside Generating Station and the MEC District Heating System consists of:

a. 20" diameter steel pipe with 4" of insulation in a 30" casing.

b. 8" diameter steel pipe with 1" of insulation in a 12" casing.

The other casing of the line would be of welded construction and protected with a cathodic protection system. The approximate length of the steam and condensate lines is 20,000 feet.

3. Forty concrete manholes spaced approximately every 500 feet are constructed to allow maintenance of the steam line. Each manhole will contain:

a. expansion joints 20" and 8" diameter.

b. anchors.

c. traps for the removal of condensate generated in the steam lines.

d. insulation.

TABLE 3-6 (cont'd)

4. Two condensate pumps rated 400 gpm at 300 psi are required to return condensate to the Riverside Plant.

5. Double casings for crossing of the Mississippi River and several railroad lines are required for the underground steam system.

TABLE 3-7
ENGINEERING DESIGN SPECIFICATION
OF EQUIPMENT FOR COAL AND OIL FIRED BOILER

1. Boiler

Shop assembled water tube boiler fitted with a traveling grate spreader stoker, a design capacity of 200,000 lb/hr saturated steam at 250 psig; boiler efficiency is 84 percent; boiler includes instrumentation, controls, and access platforms. The boiler would be desinged to fire eastern Kentucky bituminous coal or residual oil. The following standard components will be included in the boiler manufacturer's scope of supply:

a. forced draft and induced draft fans and drives.
b. continuous ash discharge stocker.
c. air preheaters and heaters.
d. soot blowers.
e. connecting duct work and insulation.

2. Coal Handling Equipment

Coal unloading and handling system includes the following major equipment:

a. truck hopper with grating size 14' X 32'.
b. 20' inclined belt feeder with 3 hp motor.
c. 24' belt conveyor included with 3 hp motor.
d. 94' center-to-center bucket elevator with 25 hp motor.
e. 120' belt conveyor with 5 hp motor.

TABLE 3-7 (cont'd)

f. 30' belt conveyor with 3 hp motor, complete with a tripper conveyor having a 2 hp motor.

g. bunker to stoker equipment which would be complete with two gates, scales, and conical distributors. The scales would have 3/4 hp motors.

h. control panel to contain the necessary lights, switches, etc., for the system.

3. Ash Handling Equipment

Ash handling system includes the following major components:

a. 14' X 28' bin with no enclosure to be erected inside the existing building.

b. four-door bottom ash hopper and 8" main lines to bin.

c. 6' economizer branch piping.

d. 6' air heater branch piping.

e. six inch baghouse branch piping.

f. bag filter.

g. set bag filter controls.

h. two vacuum pumps.

i. silo unloading equipment.

j. main control package.

TABLE 3-7 (cont'd)

4. Air Pollution Control Equipment

Air pollution control equipment includes a baghouse with an efficiency of 99+ percent and an air/cloth ratio of 3.15.

5. Mechanical Collector

A mechanical collector with an efficiency of 70-80 percent for precleaner to baghouse. Scope of supply includes tubes, structural steel, insulation, and equipment installation as a unit.

6. Stacks

		Existing	New
Number:		2	1
Height above grade:		110 ft.	160 ft.
Exit diameter:		4.92 ft.	5.86 ft.*
Flue gas:	Exit velocity	61.7 ft./sec.	61.7 ft./sec.
	Exit volume rate	70,390 ACFM	100,000 ACFM
	Exist temperature	301°F	301°F

Existing stacks will be extended to 160 feet.

7. Offsite coal pile storage is required. For 90 days reserve of coal about 1.7 acres of land would be required to provide a coal pile 15 feet high. (See appendix for calculation). Existing oil tanks would be used for oil storage.

TABLE 3-7 (cont'd)

8. Existing plant equipment

Relocation of deaerator and water treating equipment is required to install the boiler.

9. Boiler feed pumps

Two multistage horizontal centrifugal pumps rated 400 gallons per minute at 300 psi with electric motor drives.

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* See appendix A for calculation.

TABLE 3-8
SOLID WASTES FROM BASE AND ALTERNATE FUELS

Fuel	Ash (Tons/yr)
Oil/gas	3.12
Coal	1264
Petroleum Coke/Coal	1533
Refused Derived Fuel	8505
Coal-Oil Mixture	310*

(See appendix A for calculations)

* Based on 60 percent, 40 percent coal.

4.0 COST ESTIMATES

The estimated installation and annual operating costs for each of the alternative fuels considered for MEC's proposed boiler are summarized in tables 4-1 through 4-8.

Equipment costs for major items were obtained from suppliers by AMAF. Equipment cost data from the MEC Fuels Decision Report was used only if substantiated by a letter from an equipment supplier. Other costs were estimated by AMAF using standard industry sources of estimating data, such as Means Cost Data.

When reviewing the estimates presented in this report with the estimates prepared by MEC's consultant, Henningson, Durham, and Richardson (HDR), a substantial difference in the costs for modifications to the existing building and construction of additional building space will be noted. HDR's cost estimates have been calculated on the basis of $4.50 per cubic foot of building volume. AMAF's estimates have been made on the basis of estimated material quantities and published material and labor costs from Means Cost Data, 1980 Edition.

Although HDR's average building cost of $\$4.50/ft^3$ is reasonable for new construction of this type, AMAF believes that the use of this calculation basis for this project considerably overstates the actual costs that would be incurred. HDR's estimate of $3,967,200 for modifying the existing building to accommodate a coal fired boiler is based on the entire volume and the structure and not on the volume to be added to the present structure. At $4.50/ft^3$, the cost of the added volume would be $1,108,000; however, this volume basis estimate includes structural steel, foundations, and other items already in place. Based on HDR's detailed design and engineering work, AMAF estimates that the actual cost of construction required to modify the existing building would be $434,000.

Although HDR's estimate of $1,675,800 for the baghouse building appears reasonable if all of the steel in the building is included as a building cost line item, AMAF notes that most of the major structural steel in this building would be furnished by the baghouse manufacturer and would be included in the cost of this equipment. For this reason, AMAF's estimate of $683,000 more accurately reflects the cost of the baghouse building.

TABLE 4.1. MINNEGASCO ENERGY CENTER COST ESTIMATE FOR BASE & ALTERNATIVE FUELS

Direct Costs	Oil/ Natural Gas	Coal	Petroleum Coke/Coal	Refuse Derived Fuel	Steam	Coal-Oil Mixture	Coal-Oil Dual Fuel Firing
Buildings							
Modifications to Existing Buildings	40,000	434,000	434,000	434,000	NR	434,000	434,000
Baghouse Building	NR	683,000	633,000	NR	NR	NR	NR
Coal Unloading Building	NR	188,000	138,000	188,000	NR	188,000	188,000
Coal Conveyor Enclosure	NR	48,000	48,000	48,000	NR	48,000	48,000
ESP Building	NR	NR	NR	683,000	NR	683,000	683,000
Ash Silo Enclosure	NR	33,000	33,000	33,000	NR	33,000	33,000
Total Building Cost	40,000	1,386,000	1,336,000	1,386,000	0	1,386,000	1,386,000
Land	NR	NR	NR	NR	140,400	NR	NR
Pollution Control Equipment							
Mechanical Collector	60,500	60,500	60,500	NR	NR	NR	NR
Electrostatic Precipitator	NR	NR	NR	836,600	NR	836,600	836,600
Baghouse	NR	1,033,200	1,033,200	NR	NR	NR	NR
Total Pollution Control	60,500	1,093,700	1,093,700	836,600	0	836,600	836,600

Direct Costs (cont'd)	Oil/ Natural Gas	Coal	Petroleum Coke/Coal	Refuse Derived Fuel	Steam	Coal-Oil Mixture	Coal-Oil Dual Fuel Firing
Other Equipment							
Boiler Package	1,578,800	4,183,200	4,183,200	4,392,400	NR	5,342,400	5,300,000
Piping, Valves, & Insulation	50,000	50,500	50,500	50,500	7,546,900	50,500	50,500
Boiler Feed Pumps	9,600	9,600	9,600	9,600	NR	9,600	9,600
Condensate Pumps	NR	NR	NR	NR	9,600	NR	NR
Stack	398,700	466,200	466,200	466,200	466,200	466,200	466,200
Ductwork	18,000	45,000	45,000	45,000	NR	45,000	45,000
Coal Handling	NR	630,000	630,000	630,000	NR	630,000	630,000
Coal (RDF) Bunker	NR	187,000	187,000	187,000	NR	187,000	187,000
Ash Handling	NR	517,800	517,800	517,800	NR	517,800	517,800
Equipment Foundations and Support Steel	29,600	53,000	53,000	53,000	100	54,100	53,000
Electrical Wiring	173,200	601,400	601,400	597,500	1,400	673,600	601,400
Total Other Equipment	2,254,900	6,743,700	6,743,700	6,949,000	7,558,000	7,976,200	7,860,500
Total Direct Cost	2,355,400	9,223,400	9,223,400	9,171,600	7,698,400	10,198,800	10,083,100
Indirect Costs (35 Percent Direct Costs)	824,400	3,228,200	3,228,200	3,210,100	2,694,400	3,569,600	3,529,100
Subtotal	3,179,800	12,451,600	12,451,600	12,381,700	10,392,800	13,768,400	13,612,200
Contingency (5% Oil, 20% All Others)	159,000	2,490,300	2,490,300	2,476,300	2,078,600	2,753,700	2,722,400
Total Capital Cost	3,338,800	14,941,900	14,941,900	14,858,000	12,471,400	16,522,100	16,334,600

TABLE 4.1. MINNEGASCO ENERGY CENTER COST ESTIMATE FOR BASE & ALTERNATIVE FUELS (cont'd)

Direct Costs (cont'd)	Oil/ Natural Gas	Coal	Petroleum Coke/Coal	Refuse Derived Fuel	Steam	Coal-Oil Mixture	Coal-Oil Dual Fuel Firing
Annual O&M Costs							
Electrical Power	23,500	92,900	92,900	122,400	7,100	131,700	92,900
Operating Labor	25,000	100,000	100,000	100,000	50,000	50,000	100,000
Maintenance	10,000	45,000	45,000	30,000	15,000	60,000	45,000
Total O&M Costs	58,500	237,900	237,900	252,400	72,100	241,700	237,900

TABLE 4.1 MINNEGASCO ENERGY CENTER COST ESTIMATE FOR BASE & ALTERNATIVE FUELS (cont'd)

NOTES FOR COST ESTIMATES

1. Petroleum coke, refuse-derived fuel, and coal oil mixture preparation plants will be constructed and operated by the fuel supplier. Fuel preparation plant costs are not included in the cost estimates.

2. Purchased steam alternative does not include modifications at the Riverside Plant of Northern States Power Company.

3. Owner's costs, escalation, interest, taxes, and permit fees are not included.

4. O&M costs for electrical power and maintenance based on 26 percent load factor. Fuel costs are not included.

5. Engineering work begins January 2, 1981, with initial boiler firing on August 1, 1982, and commercial operation on September 1, 1982.

6. Fuel alternative designs have been estimated using the plant configuration described in the Fuels Decision Report.

7. Dollar amounts shown in the estimates are December 1979 dollars.

TABLE 4.2 OIL/NATURAL GAS FIRED BOILER

CAPITAL OUTLAYS BY YEAR
(Thousands of 1979 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0.0	31.2	8.8	0.0
Land	0.0	0.0	0.0	0.0
Pollution Control Equipment	0.0	0.0	60.5	0.0
All Other Direct Costs	0.0	418.0	1836.9	0.0
Total Direct Costs	0.0	449.2	1906.2	0.0
Indirect Costs	0.0	157.2	667.2	0.0
(35 Percent of Direct)				
Contingency	0.0	30.3	128.7	0.0
(5 Percent of Indirect and Direct)				
Total Capital Costs	0.0	636.7	2702.1	0.0

TABLE 4.3 COAL FIRED BOILER

CAPITAL OUTLAYS BY YEAR
(Thousands of 1978 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0	792.1	593.9	0
Land	0	0.0	0.0	0
Pollution Control Equipment	0	534.0	559.7	0
All Other Direct Costs	0	1,657.6	5,086.1	0
Total Direct Costs	0	2,983.7	6,239.7	0
Indirect Costs	0	1,044.3	2,183.9	0
(35 Percent of Direct)				
Contingency	0	805.6	1,684.7	0
(20 Percent of Direct and Indirect)				
Total Capital Costs	0	4,833.6	10,108.3	0

TABLE 4.4 PETROLEUM COKE/COAL FIRED BOILER

CAPITAL OUTLAYS BY YEAR
(Thousands of 1979 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0	792.1	593.9	0
Land	0	0.0	0.0	0
Pollution Control Equipment	0	534.0	559.7	0
All Other Direct Costs	0	1,657.6	5,086.1	0
Total Direct Costs	0	2,983.7	6,239.7	0
Indirect Costs	0	1,044.3	2,183.9	0
(35 Percent of Direct)				
Contingency	0	805.6	1,684.7	0
(20 Percent of Indirect and Direct)				
Total Capital Costs	0	4,833.6	10,108.3	0

TABLE 4.5 RDF-FIRED BOILER

CAPITAL OUTLAYS BY YEAR
(Thousands of 1979 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0	792.1	593.9	0
Land	0	0.0	0.0	0
Pollution Control Equipment	0	519.4	317.2	0
All Other Direct Costs	0	1,653.6	5,295.4	0
Total Direct Costs	0	2,965.1	6,206.5	0
Indirect Costs	0	1,037.8	2,172.3	0
(35 Percent of Direct)				
Contingency	0	800.6	1,675.7	0
(20 Percent of Indirect and Direct)				
Total Capital Costs	0	4,803.5	10,054.5	0

TABLE 4.6 PURCHASED STEAM

CAPITAL OUTLAYS BY YEAR
(Thousands of 1979 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0	0.0	0.0	0
Land	0	140.4	0.0	0
Pollution Control Equipment	0	0.0	0.0	0
All Other Direct Costs	0	2,004.3	5,553.7	0
Total Direct Costs	0	2,144.7	5,553.7	0
Indirect Costs	0	750.6	1,943.8	0
(35 Percent of Direct)				
Contingency	0	579.1	1,499.5	0
(20 Percent of Indirect and Direct)				
Total Capital Costs	0	3,474.4	8,997.0	0

TABLE 4.7 COAL-OIL MIXTURE FIRED BOILER

CAPITAL OUTLAYS BY YEAR
(Thousands of 1979 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0	792.1	593.9	0
Land	0	0.0	0.0	0
Pollution Control Equipment	0	519.4	317.2	0
All Other Direct Costs	0	1,751.1	6,225.1	0
Total Direct Costs	0	3,062.6	7,136.2	0
Indirect Costs	0	1,071.9	2,497.7	0
(35 Percent of Direct)				
Contingency	0	826.9	1,926.8	0
(20 Percent of Indirect and Direct)				
Total Capital Costs	0	4,961.4	11,560.7	0

TABLE 4.8 COAL-OIL DUAL FUEL FIRING CAPABILITY

CAPITAL OUTLAYS BY YEAR
(Thousands in 1979 Dollars)

Description	1980	1981	1982	1983
Direct Costs				
Buildings	0	792.1	593.9	0
Land	0	0.0	0.0	0
Pollution Control Equipment	0	519.4	317.2	0
All Other Direct Costs	0	1,725.7	6,134.8	0
Total Direct Costs	0	3,037.2	7,045.9	0
Indirect Costs (35 Percent of Direct)	0	1,059.7	2,469.4	0
Contingency (20 Percent of Direct and Indirect)	0	817.5	1,904.9	0
Total Capital Costs	0	4,914.4	11,420.2	0

APPENDIX A

CALCULATIONS

Waste Calculations for Solid Fuels

Coal:

Ash content: 6.35%

Sulfur Content: 0.66%

Based on 459 million lb of steam production per year.

East Kentucky coal consumed: 19,910 tons

Amount of ash produced: 19,910 tons/yr x 0.0635 = 1264 tons/yr

Petroleum Coke Mixture:

	Coke	Montana Coal
Ash content:	0.53%	6.7%
Sulfur content:	4.45%	0.5%

Petroleum coke consumed: 6000 tons

Montana Coal consumed: 22,400 tons

Amount of ash produced (6000 tons/yr x 0.0053) + 22,400 tons/yr x 0.067)

= 1533 tons/yr

Refuse Derived Fuel (RDF):

Ash content: 15%

Sulfur content: 0.15%

RDF consumed: 56,700 tons

Amount of ash produced: 56,700 tons x 0.15 = 8505 tons/yr

Coal/Oil Mixture (COM):

Ash content: 6.35% (east Kentucky coal)

COM (coal) consumed: 4880 tons

Amount of ash produced: 4880 tons/yr x 0.0635 = 310 tons/yr

Sludge Calculation for Petroleum Coke

From Danskammer report:

485 tons per day are produced from 4 x 275,000 ACFM . 2% sulfur coal fuel, and the scrubber has an efficiency of 90%.

Now, for 100,000 ACFM, 4.45% sulfur coal, and the scrubber has an efficiency of 52% (quotation from Niro Atomizer, Inc.)

$$485 \text{ tons/day} \times \frac{100,000}{4 \times 275,000} \times \frac{4.45\%}{2\%} \times \frac{52\%}{90\%} = 56.68 \text{ tons/day}$$

For a year with 26% load factor.

Sludge produced will be: 56.68 tons x 365 x 0.26

= 5379 tons/yr

= <u>5400 tons/yr</u>

Calculation of Diameters of Steam Pipe and Condensate Return Piping

Steam flow: 200,000 lb/hr

Density of steam at 250 psi saturated:

$$\frac{1}{1.8448}\ \text{lb/ft}^3 = 0.5421\ \text{lb/ft}^3$$

Density of condensate return at 175°F:

$$\frac{1}{0.016479}\ \text{lb/ft}^3 = 60.68\ \text{lb/ft}^3$$

Average steam velocity: 8,000 ft/min

Average condensate return velocity: 10 ft/sec

Using the formula: $Q = pVA$

where Q is the flow rate

p is the density of fluid

V is the velocity of flow

A is the area of pipe

For steam pipe

$$A = \frac{Q}{pV}$$

$$= \frac{200{,}000\ \#/\text{hr}}{0.5421\ \#/\text{ft}^3 \times 8000\ \text{ft/min} \times 60\ \text{min/hr}}\ \text{ft}^2 = 0.7686$$

$$\pi r^2 = A$$

$$r = \sqrt{\frac{A}{\pi}} = 0.4946\ \text{ft}$$

Diameter = 2r = 0.9893 ft

= 11.87"

Pipe required is <u>12"</u> Schedule 40 (with I.D. = 11.938" and wall thickness = 0.406")

For condensate return pipe:

Since there is a 4% loss of flow from condensate,

$$A = \frac{200{,}000\ \#/\text{hr} \times 0.96\ \text{ft}^2}{60.68\ \#/\text{ft}^3 \times 10\ \text{ft/sec} \times 3600\ \text{sec/hr}} = 0.0879\ \text{ft}^2$$

$$r = \sqrt{\frac{A}{\pi}} = 0.1673 \text{ ft}$$

$$\text{Diameter} = 2r = 0.3345 \text{ ft}$$

$$= 4.014''$$

Pipe required for condensate return is <u>4"</u> Schedule 40 (with I.D. = 4.026" and wall thickness 0.237")

For condensate piping to NSP:

Pressure drop through 4 " pipe at 200,000 #/hr (400 gpm) flow rate:

$$\frac{15.5 \text{ ft}}{100 \text{ ft}} \text{ X } 20{,}000 \text{ ft X } \frac{1 \text{ psi}}{2.31 \text{ ft}} = 1341 \text{ psi (too high)}$$

Pressure drop through 8" pipe at 200,000 #/hr (400 gpm) flow rate:

$$\frac{0.433 \text{ ft}}{100 \text{ ft}} \text{ X } 20{,}000 \text{ ft X } \frac{1 \text{ psi}}{2.31} = 37.5 \text{ psi}$$

Use 8 inch diameter pipe for NSP condensate piping.

NOTE: Densities of steam and water are from "Steam Tables" by Keenan, Keys, Hill & Moore.

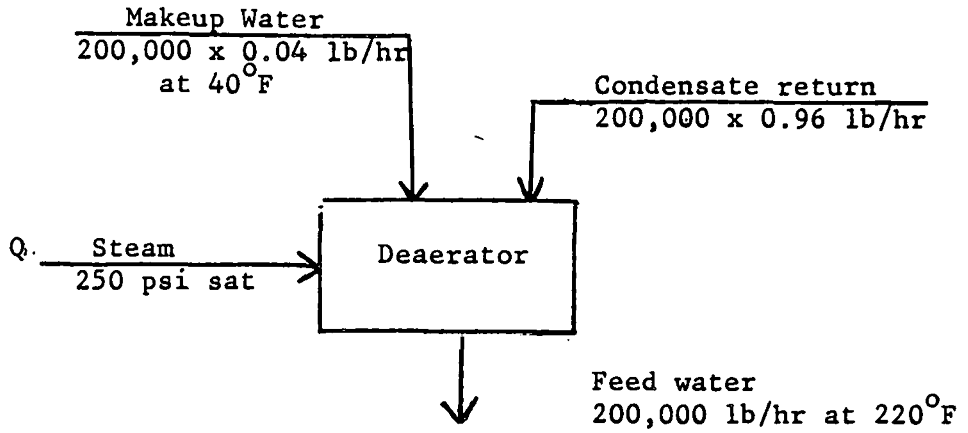
Velocity of steam is from "Flow of Fluids Through Valves, Fittings, and Pipe" by crane.

Size of pipe is from "Piping Engineering" by Tube Turns Division of Chemtron Corporation.

Pressure drop data is from "Cameron Hydraulic Data" by Ingersoll-Rand.

Calculation for piping Estimate

Assume 200' steam pipe from boiler to the deaerator.



Assume city well water is 40°F

Energy Balance:

200,000 lb/hr x 188.22 Btu/lb = 200,000 lb/hr x 0.96 x 142.98 Btu/lb + 200,000 lb/hr x 0.04 x 8.02 Btu/lb + Q lb/hr x 1202.1 Btu/hr

Q = 8425 lb/hr

Where Q is the steam required to be used in the deaerator.

Using the formula: Q=pVA

where p = density of steam in lb/ft^3

V = velocity of steam in ft/sec

A = area of pipe in ft^2

p = 0.5421 lb/ft^3 for steam at 250 psi, saturated (from steam tables)

V = 8000 ft/min (average) (from Flow of Fluids by Crane)

$$A = \pi r^2 = \frac{Q}{pV} = \frac{8425 \text{ lb/hr}}{0.5421 \text{ lb/ft}^3 \times 8000 \text{ ft/min} \times 60 \text{ min/hr}}$$

$$\text{Diameter} = 2r = 2\sqrt{\frac{A}{pV}} = 2 \times 0.01015 \text{ ft} = 0.2030 \text{ ft} = 2.44''$$

Pipe required is 2½" Schedule 40 (with I.D. - 2.469", wall thickness = 0.203)

Calculation of Stack Exit Diameter for a Coal-Fired Boiler

For the existing stack: flue gas flow rate = 70,390 ACFM

exit diameter of stack = 4.92 ft.

Assume same exit velocity for both stacks.

Assume flue gas flow rate for the coal-fired boiler is 100,000 ACFM.

Using the formula: $Q = VA$

where Q = flow rate

V = velocity of flow

A = area of gas flow

With same exit velocity: $$\frac{Q_1}{A_1} = \frac{Q_2}{A_2}$$

$$A_2 = A_1 \frac{Q_2}{Q_1} = r_1^2 \frac{Q_2}{Q_1}$$

or $$\pi r_2^2 = \pi r_1^2 \frac{Q_2}{Q_1}$$

$$r_2 = r_1\sqrt{\frac{Q_2}{Q_1}} = \frac{4.92}{2} \times \sqrt{\frac{100,000}{70,390}} = 2.93 \text{ ft}$$

The stack exit diameter for the coal-fired boiler:

$$2r_2 = 2 \times 2.93 \text{ ft}$$

$$= \underline{5.86 \text{ ft}}$$

Calculation of Stack Diameter for a Coal-Fired Boiler

For the existing stack: flow gas flow rate = 70,390 ACFM

diameter of stack = 7 ft.

Assume same velocity of flue gas for both stack.

Assume flue gas flow rate for the coal-fired boiler is 100,000 ACFM

Using the formula: $Q = VA$

where Q = flow rate

V = velocity of flow

A = area of gas flow

with some velocity: $$\frac{Q_1}{A_1} = \frac{Q_2}{A_2}$$

$$A_2 = A_1 \frac{Q_2}{Q_1} = \pi r_1^2 \frac{Q_2}{Q_1}$$

or $$\pi r_2^2 = \pi r_1^2 \frac{Q_2}{Q_1}$$

$$r_2 = r_1 \sqrt{\frac{Q_2}{Q_1}} = \frac{7}{2} x \sqrt{\frac{100,000}{70,390}} = 4.17 \text{ ft.}$$

The diameter of the stack for the coal-fired boiler:

$2r_2$ = 2 x 4.17 ft.

= 8.34 ft.

= 8'4"

Calculation of Offsite Coal Pile Storage

Capacity of Boiler:	200,000 lb steam/hr
Heat value of steam:	1,300 Btu/lb steam
Heating value of coal:	8,500 Btu/lb coal
Density of coal:	60 lb/ft^3

1 acre = 43,560 ft^2

Assume 24 hrs operation, for a 90-day reserve of coal and a 15 ft. high coal pile.

Site required:

200,000 lb steam/hr x 1300 Btu/lb steam x 24 hrs/day x 90 days ÷ 60 lb/ft^3

÷ 8500 Btu/lb coal ÷ 15 ft. high ÷ 43560 ft^2/acre

= 1.69 acres

= 1.70 acres

Calculation of Offsite Petroleum Coke/Coal Pile Storage

Capacity of Boiler:	200,000 lb/hr	
Heat value of steam:	1,300 Btu/lb steam	
Percent in fuel mix:	Petroleum Coke:	30%
	Coal:	70%
Heating value:	Petroleum Coke:	14,200 Btu/lb
	Coal:	8,755 Btu/lb
Average density of the mixture:		60 lb/ft^3

1 acre = 43,560 ft^2

Average heating value of the mixture:

(14,200 x 0.30 + 8,755 x 0.70) Btu/lb = 10388.5 Btu/lb = 10400 Btu/lb

Assume 24 hours operation.

For a 90-day reserve of the mixture and a 15-ft high coal pile, site required:

$$\frac{200{,}000 \text{ lb/hr} \times 1300 \text{ Btu/lb}}{10400 \text{ Btu/lb}} \times \frac{24 \text{ hrs}}{\text{day}} \times 90 \text{ days} \div \frac{60 \text{ lb}}{\text{ft}^3} \div 15 \text{ ft high} \div 43560 \frac{\text{ft}^2}{\text{acre}}$$

= 1.38 acres

= <u>1.4 acres</u>

APPENDIX B

PHOTOGRAPHS

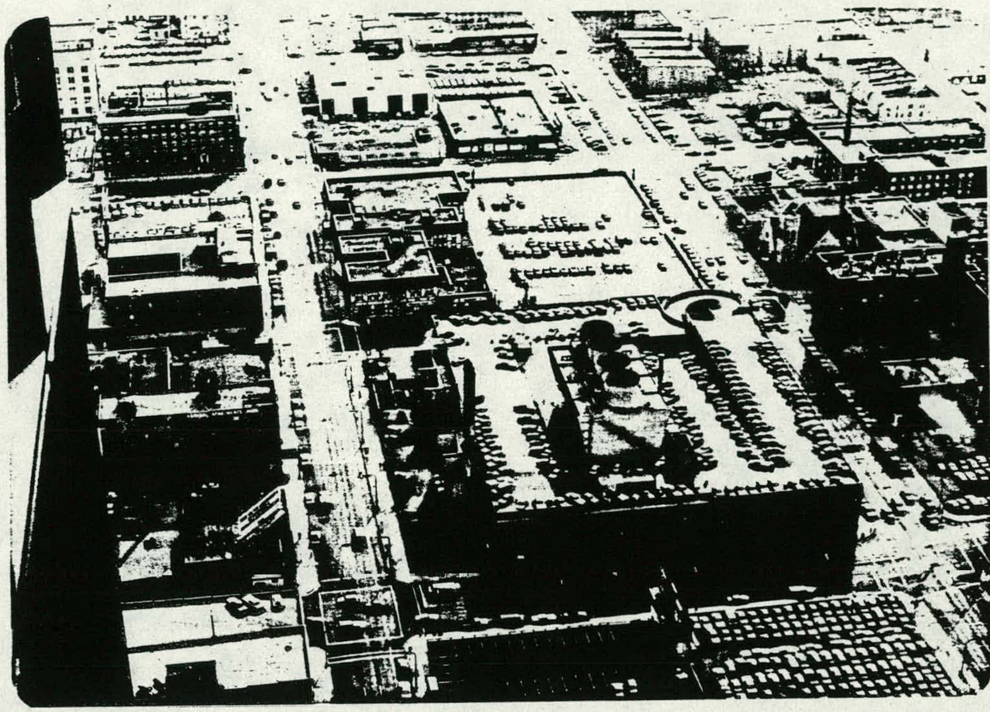


Photo No. 1 - View of Minnegasco Energy Center
from IDS Tower

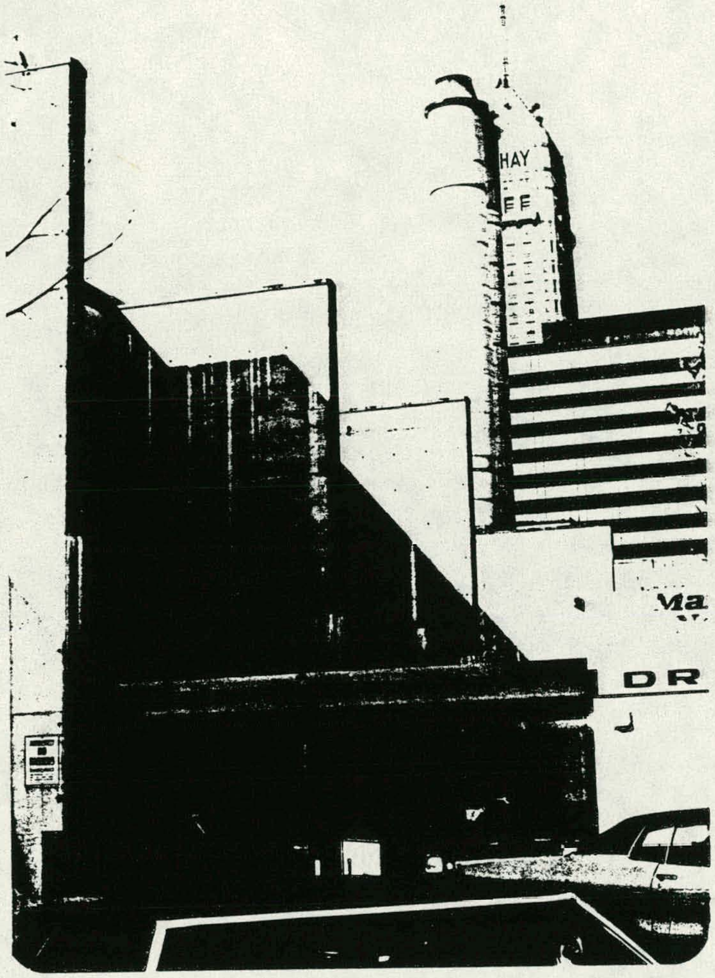


Photo No. 2
North Wall of MEC
Building (Bank in
Foreground)

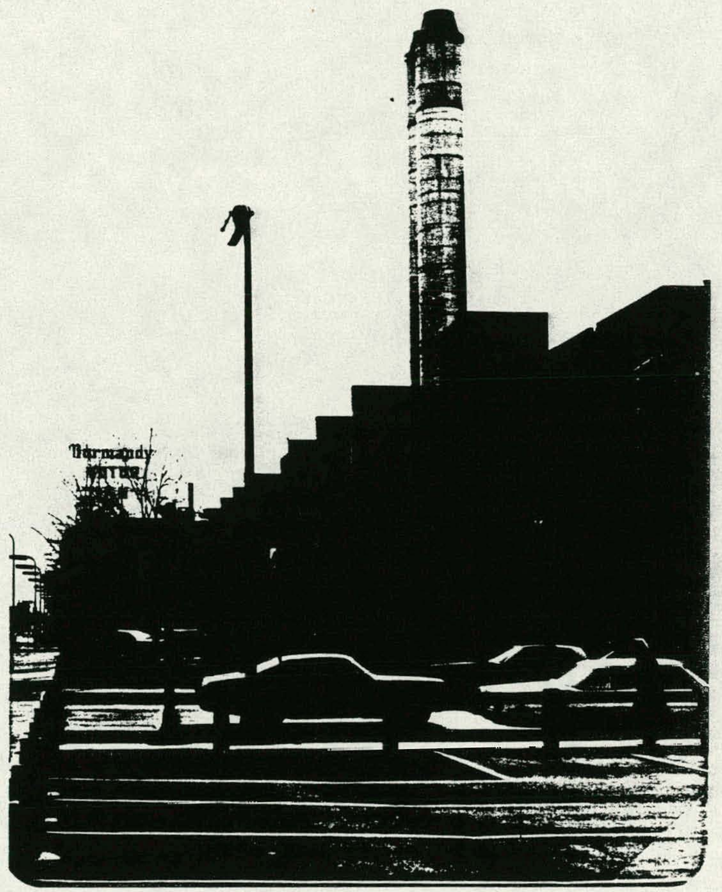


Photo No. 3
North Wall of MEC
Building Looking East

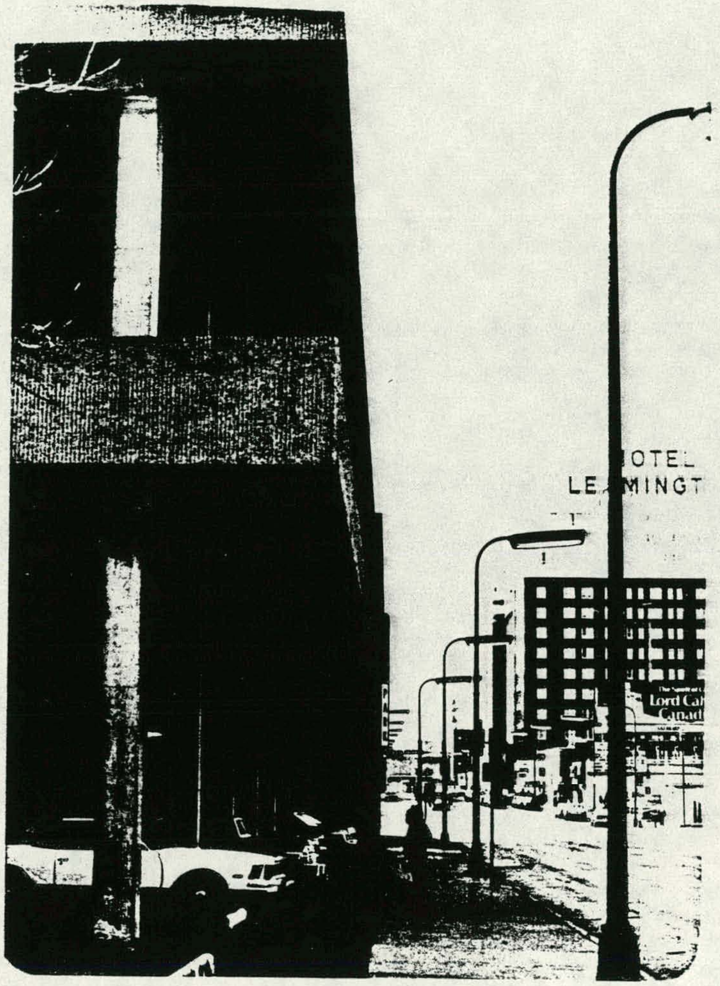


Photo No. 4
West Wall of MEC
Building Looking South

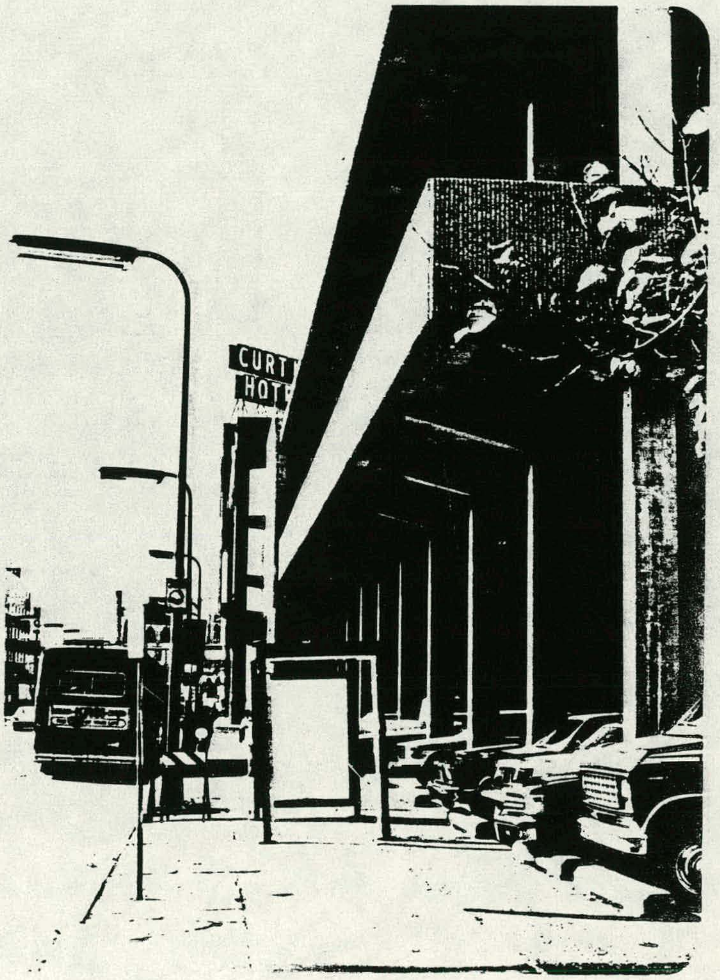


Photo No. 5
East Wall of MEC
Building Looking South

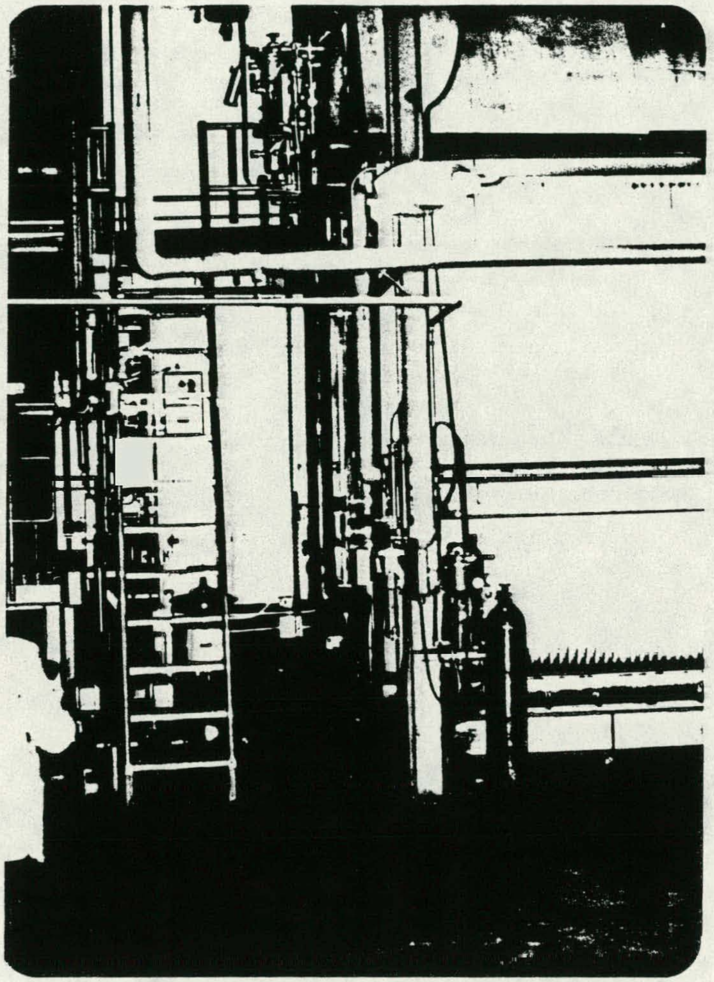


Photo No. 6
Existing Oil Fired Boilers
Boiler No. 2 in Foreground

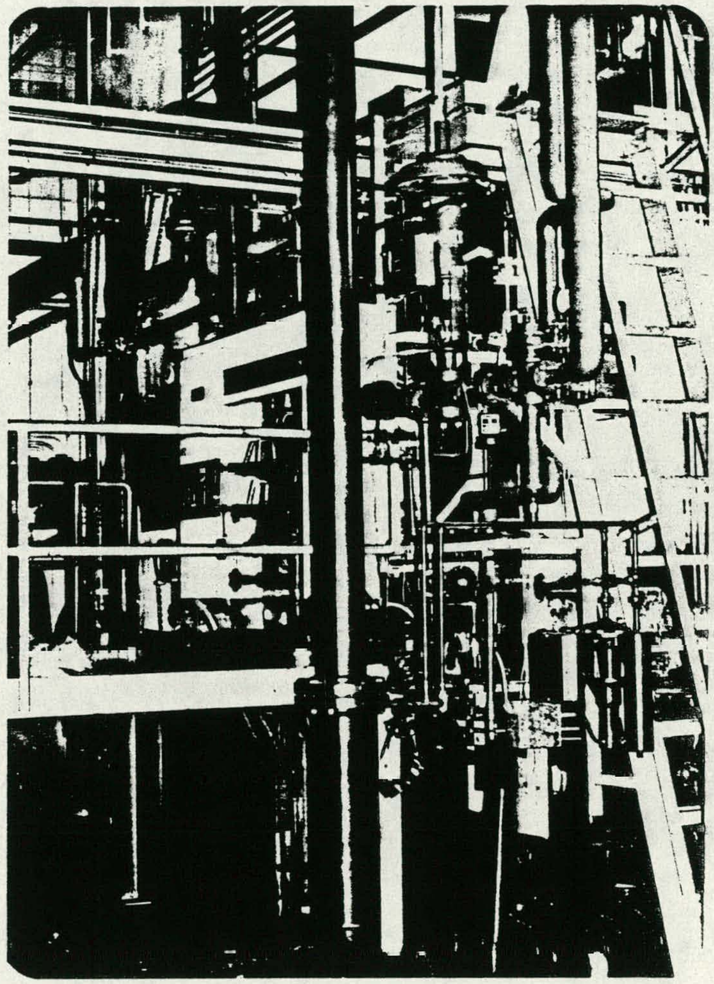


Photo No. 7
Front of No. 2 Boiler

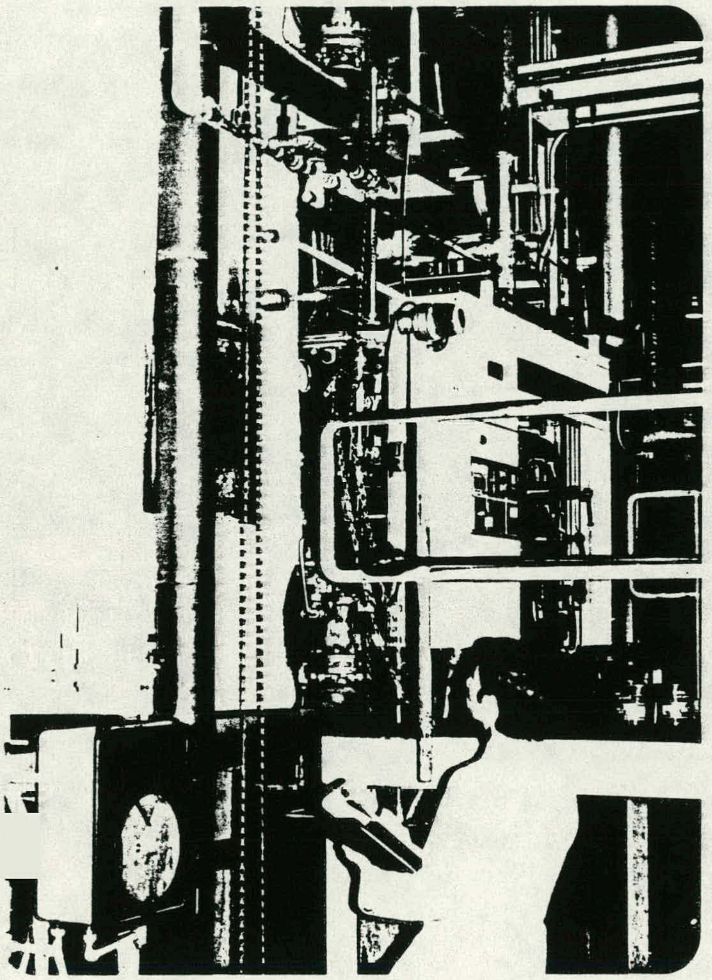


Photo No. 8
Fuel Piping on Front
of Boiler

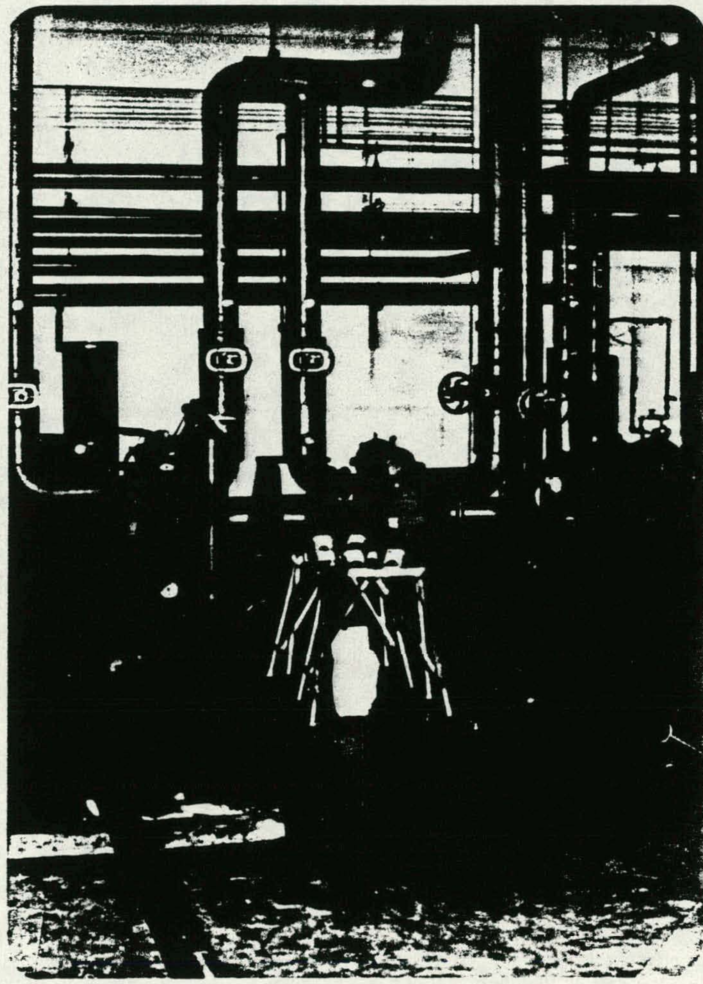
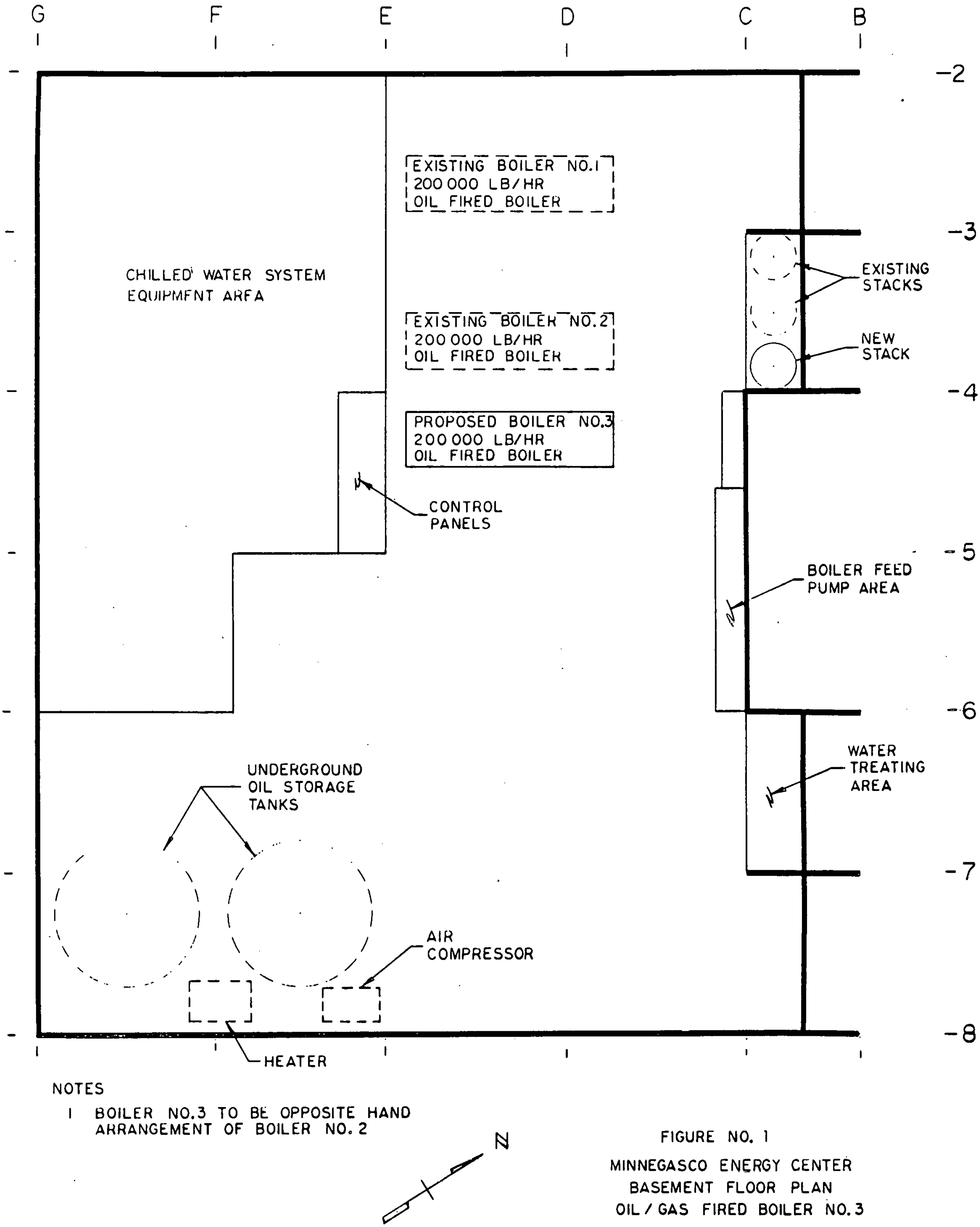


Photo No. 9
Site of Proposed Boiler No. 3

APPENDIX C

DRAWINGS



NOTES

1 BOILER NO.3 TO BE OPPOSITE HAND ARRANGEMENT OF BOILER NO. 2

FIGURE NO. 1

MINNEGASCO ENERGY CENTER
BASEMENT FLOOR PLAN
OIL / GAS FIRED BOILER NO. 3

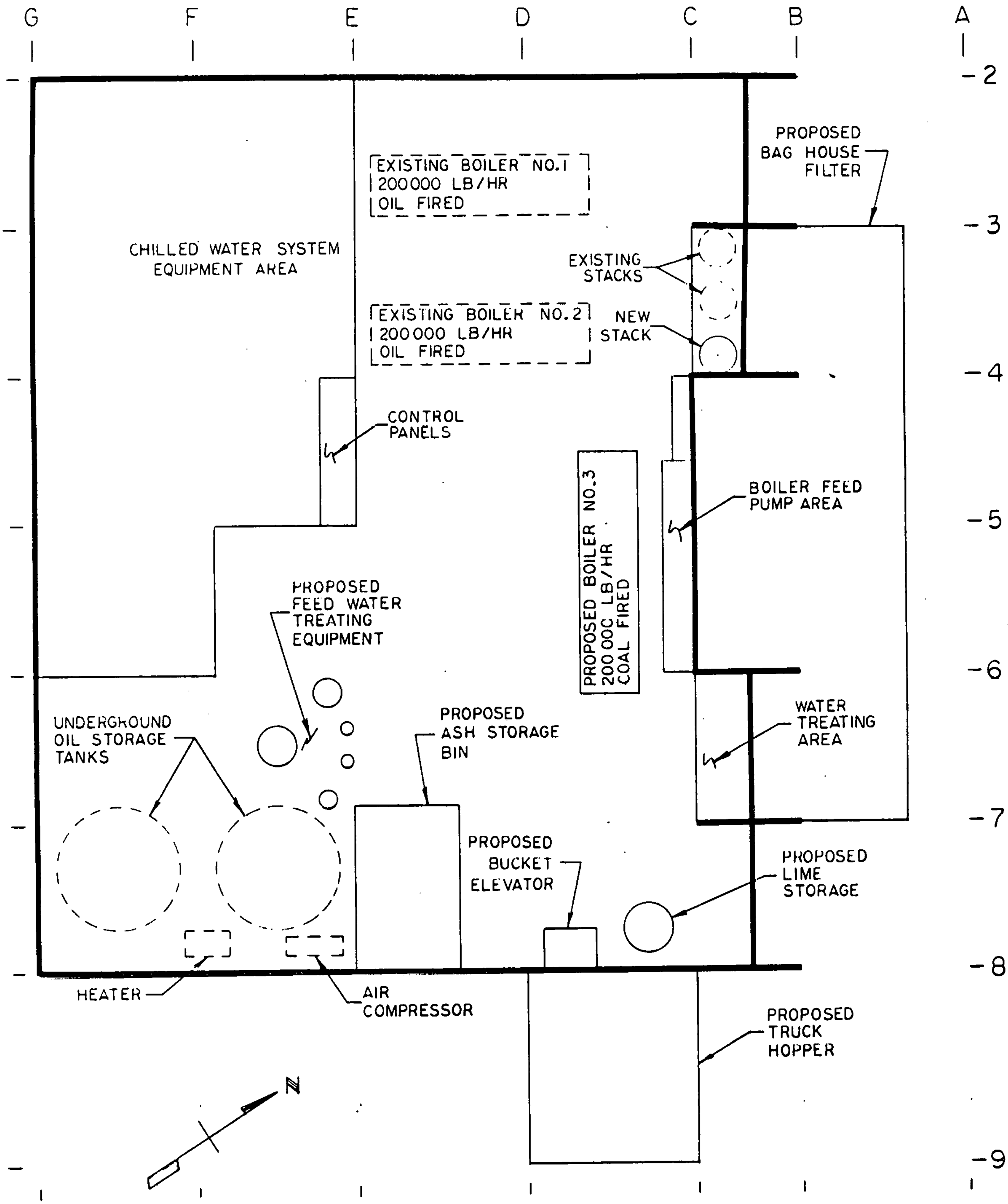


FIGURE NO. 2

MINNEGASCO ENERGY CENTER
BASEMENT FLOOR PLAN
COAL FIRED BOILER NO.3

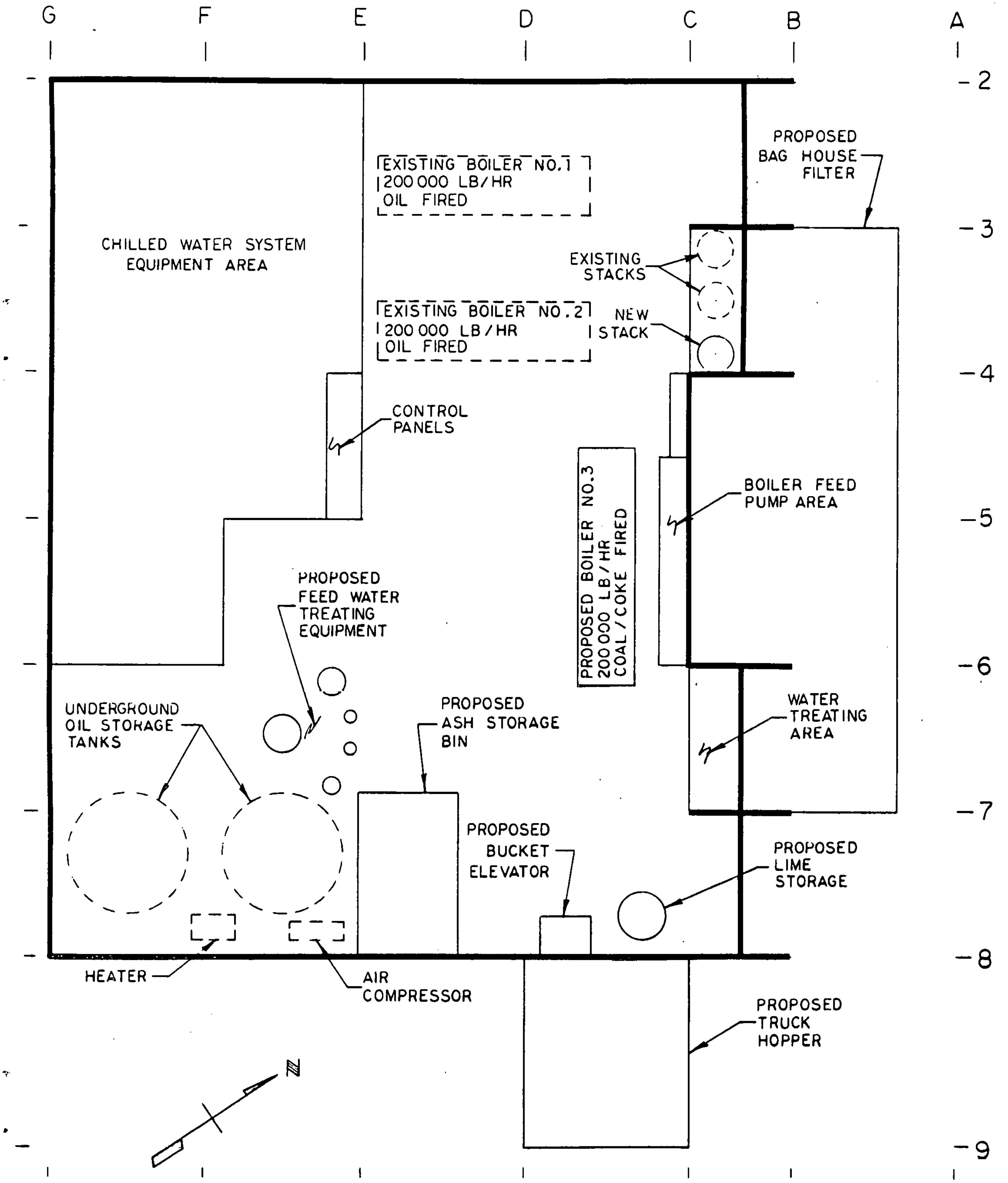


FIGURE NO. 3

MINNEGASCO ENERGY CENTER
BASEMENT FLOOR PLAN
PETROLEUM COKE-COAL
FIRED BOILER NO. 3

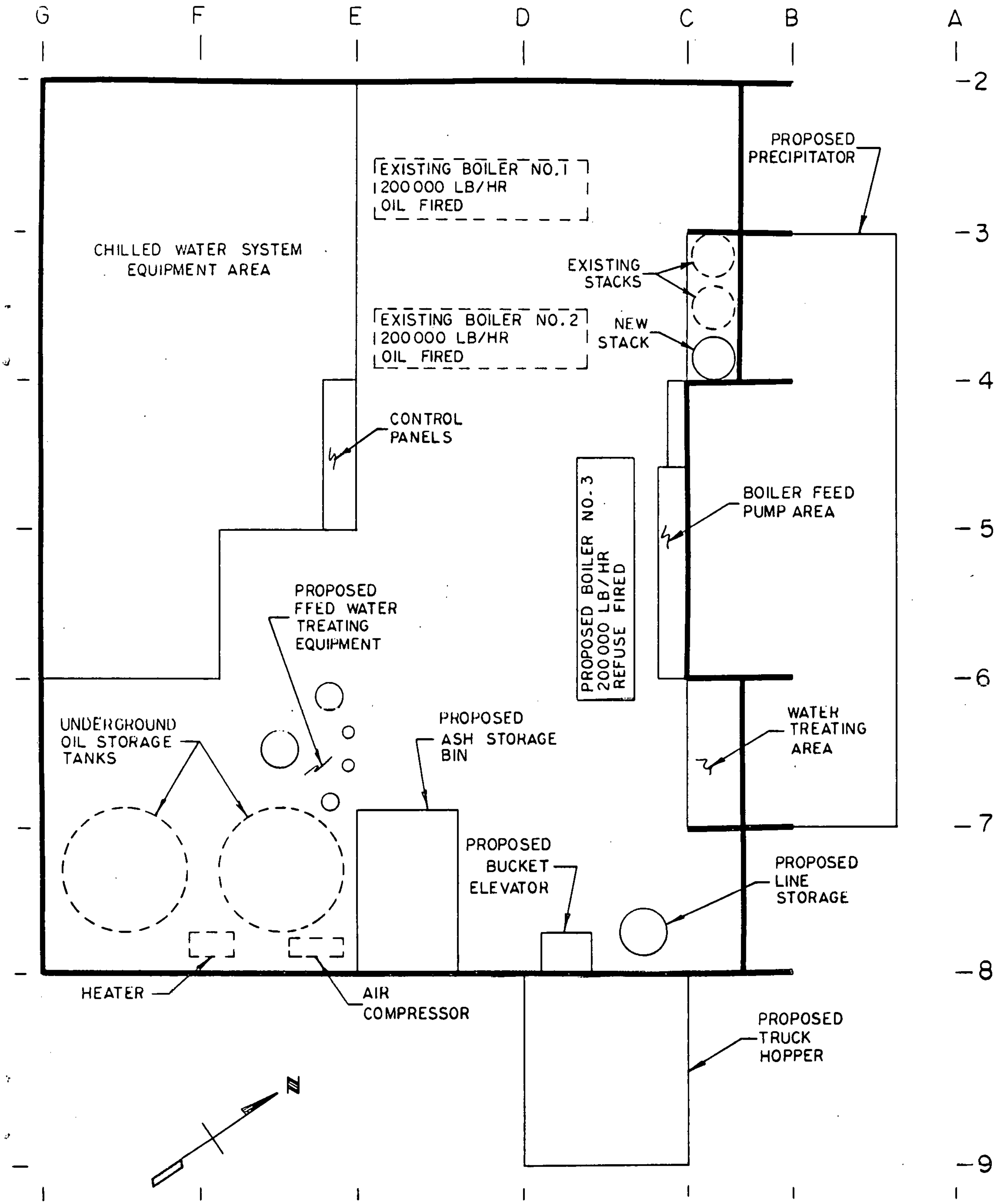


FIGURE NO. 4

MINNEGASCO ENERGY CENTER
BASEMENT FLOOR PLAN
REFUSE DERIVED FUEL FIRED
BOILER NO. 3

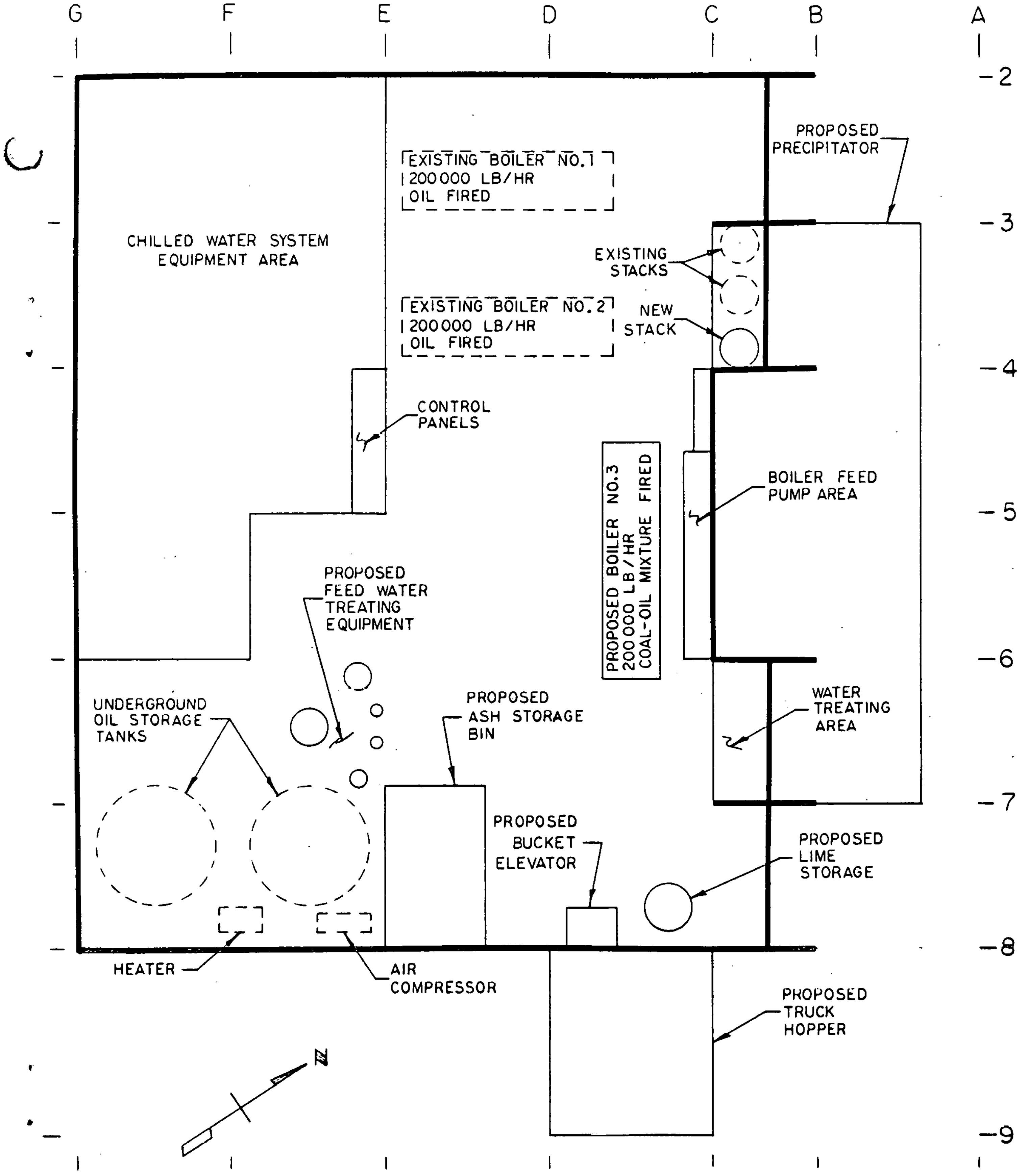


FIGURE NO. 5

MINNEGASCO ENERGY CENTER
BASEMENT FLOOR PLAN
COAL-OIL MIXTURE FIRED
BOILER NO. 3