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STUDY FOR BURNER CONTROL COAL FEED AND ASSOCIATED PULVERIZER

CAMP LEJEUNE, NORTH CAROLINA

FEBRUARY 24, 1981

Prepared By:

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TABLE OF CONTENTS

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INTRODUCTION

This study was prepared in accordance with the requirements and scope established in Contract Number N62470-80-C-3830 and a meeting held at Camp Lejeune to define the scope on September 3, 1980.

This report is complete and includes review comments. The report includes an analysis of the existing conditions and several design changes that are required to meet the safety requirements in NFPA. Also included are analyses of several items which are not necessary to meet NFPA Safety Requirements, but they are additives that should be considered. Cost estimates of the equipment and labor needed to implement these recommendations are included on Material and Labor Cost Estimate Sheets 5ND LANTDIV 4-11012/5 (Rev 10/74).

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that there are equipment and control modifications necessary to meet the NFPA requirements. Implementation of these modifications should result in improved safety and increased efficiency.

Conclusions:

1. The following conclusions are recommended and discussed in detail in this study.

   a. Fuel and air should be shut off to the pulverizer by the addition of a coal and air shut off valve at the pulverizer inlet.

   b. Primary air to the pulverizer should be measured, regulated and controlled.

   c. A steam line should be permanantly installed in the pulverizer for fire protection.

   d. The existing ignitors should be replaced with larger capacity, No. 6 oil-fired ignitors.

   e. Control changes should be made as outlined in Section C of this study for burner controls without cross feed.

2. The following items should be accomplished based on available funding or operations managements evaluations:

   a. Construct clean out box for coal pulverizer to remove coal build-up in bottom of pulverizer upon shutdown.

b. Testing of air velocities in coal pipes.

c. Sequential starting interlocks for the pulverizer and coal feeder.

d. Controls modifications to include cross feed capability of pulverizer and burners.

e. Additional pump and heater set for No. 6 fuel oil.

Recommendations:

The existing pulverizers at Building 1700 are almost 40 years old and have operated beyond their expected life. At present, replacement parts are expensive and have a long delivery time. As these pulverizers become obsolete, the parts will be more difficult to obtain.

It is recommended that replacement of the existing pulverizers and coal feeders be considered and implemented at the same time as the conclusions recommended above. This will insure an integrated system of modern equipment. By obtaining new pulverizers, many of the concerns addressed in this study will be incorporated in the new equipment or will at least have provisions for the controls and equipment suggested in the NFPA code. New equipment would be specified as meeting the NFPA code and most equipment currently supplied is built to NFPA requirements. A preliminary budget cost estimate to replace the pulverizers on each boiler is approximately $500,000 per boiler ($2,000,000 total). This cost would include the mills, feeder, exhauster, piping and controls.

The existing control drawings do not reflect the current wiring and controls and any work done to modify the burner and combustion controls should include new drawings of the entire control system.

A. PULVERIZER ANALYSIS

1. STUDY CRITERIA:

This study utilizes the National Fire Protection Association (NFPA) Codes and Standards. The two applicable standards utilized were "Standards for the Installation and Operation of Pulverized Fuel Systems NFPA 85F-1978; and "Standard for Prevention of Furnace Explosion and Pulverized Coal-Fire Multiple Burner Boiler-Furnaces", NFPA 85E-1978. It is suggested that the reader become familiar with these particular Standards. For purposes of discussion, the applicable details of these Standards are to be found in Appendix A and B following this Section. Appendix A contains the excerpts from NFPA 85F-1978 which are applicable to pulverized fuel systems and Appendix B contains excerpts of NFPA 85E-1978 which are applicable to prevention of furnace explosions.

The most important consideration of these Standards is that they are not mandatory for existing installations. However, the Standards apply to major alterations or extensions of existing equipment. NFPA Standards request that operating companies of pulverizers and boilers adopt those features of the Standard which are considered applicable and reasonable for existing installations. Please refer to paragraph 1-2.2 1-2.3 in Appendix A and Paragraphs 13 and 14 in Appendix B for exact wording of these Standards.

2. STUDY CONCLUSIONS:

a. Reports of the pulverizer continuing to run and delivering 200 to 300 pounds of coal to the furnace:

It is reported that fires continue five to seven minutes after system shutdown due to a trip. This aspect of the pulverizer mechanical system was studied extensively to verify the reports.

After shutting off the fuel supply to the pulverizer, a quantity of fuel, which is stored in the pulverizer, will be propelled to the burners by air passing through the system. Even if the pulverizer power supply is removed, the high rotary inertia of the pulverizer will continue to pump air and fuel to the burner for a considerable time period. Air and coal will be pumped out during this coast-down period.

There are two ways to prevent this from occurring. The first way is to provide a shut-off valve on the pulverizer inlet, thereby removing the capability of airflow out of the pulverizer by eliminating the airflow into it. The second way previously suggested is to shut off the exit of the pulverizer thereby preventing any material from leaving. The second alternative is not feasible. Upon blocking the outlet of the pulverizer it becomes extremely positive with respect to atmosphere. Any openings in the pulverizer casing, shaft seals, etc. will allow coal to escape into the boiler plant. This phenomenon was observed by the writer when a coal pluggage occured in the pulverizer. This creates an extremely hazardous condition and should not be allowed to occur.

The recommended alternative is to place a valve in the inlet end of the pulverizer. This will prevent air from traveling through the pulverizer and limit the amount of material that is admitted to the boiler. As this valve is closed off, the fan in the pulverizer will develop pressure and cause the pulverizer to become extremely negative. At this point in time the air will be drawn into the pulverizer through any opening in the entire pulverizer system. From information from the manufacturer of the pulverizer the amount of negative air pressure in the pulverizer can go to 20 inches of water column. As shown in the attached calculations, a nineteen inch pressure differential will limit the

coal flow to 1.157 pounds per minute which is a safe operating condition. The calculations also indicate that this could be tolerated for a time of seventeen minutes. This would be totally adequate to restore the flame at the boiler and correct any difficulties in this system without creating an explosive condition in the boiler.

The valve, as shown in the sketches, does not have to be airtight but should substantially limit the amount of air entering into the pulverizer. Design specifications are shown in sheet 7 of the calculations which limit the total amount of leakage area to 2.45 square inches. This limited amount of leakage can be achieved by careful valve design and modification of the existing pulverizer, as shown in the sketches. Modifications should be made on the inspection door of the pulverizer and to the clean-out door to provide an air tight seal for the pulverizer. There will be certain leakages around the valve shutting off the air to the pulverizer and around the shaft seals. This is unavoidable but as long as the total area of air intake is less than 2.45 square inches the pulverizer will be safe in operation.

The first step in the actual design phase of this study would be to verify the actual thickness and physical characteristics of the material of the pulverizer. The recommendations in this study call for an external load of 20 inches of water column to be placed on the surface of the pulverizer. The construction of the pulverizer should allow this load to be safely applied but this has not been thoroughly examined. Additional gussets may be needed to strengthen the casing. Interior examination will need to be done to determine if metal has been worn away by the many years of service. Stiffening will also be required in the duct area as shown on Sheet No. 9 of the calculations.

This careful examination might result in determination of damage which would require repairs of an extensive nature. This should be

done first to determine if it might be more economical to replace the pulverizer with new equipment which is designed per NFPA 85F Paragraph 2-6.1.1 which calls for 50 psig internal pressure design conditions.

b. Supply of air to the pulverizer:

Examination of the current hot air supply system to the pulverizer indicates that it does not meet the current requirements of NFPA. Specifically the system as employed does not allow for the control of the temperature of the exit air of the pulverizer. This is specifically called out on Section C4 of 85E where "Means shall be provided to control pulverizer outlet temperature within limits suitable for the coal being fired". The current method of controlling air does not meet this criteria because the adjustment is a manual one at the forced draft fan entrance to the air preheater. There is a mechanical damper in position which is set to divert approximately 50% of the air around the air preheater. This is the only means for controlling the temperature and is highly inaccessible to the boiler operator.

The current method cannot control temperature over a wide range of coal and is highly ineffective with regard to the utilization of the air preheater. With the current bypass, 50% of the capability of the air preheater is lost. This contributes to inefficiency of the entire facility.

A new hot air ducting system is proposed to meet the requirements of NFPA for temperature control of the exit temperature of the pulverizer. Essentially this system consists of modification of the existing ductwork, construction of new hot air dampers, integration of existing dampers for pressure differential control and cold air inlet. A temperature probe, controller and indicator will also be required. These proposed modifications are shown in the sketch at the end of this presentation.

The existing hot air duct to the pulverizer will be modified by ducting to the opposite side of the pulverizer. The existing ductwork will be removed and disposed of. A new screen will be placed over the inlet of the existing duct which will serve as the cold air supply for the pulverizer. New tight shut-off dampers will be provided so as to control the amount of hot air entering the pulverizer. The existing set of dampers will be utilized to provide for air inlet suction pressure. The existing controller for achieving a negative 0.7 inches of water column will not be reused. It will be replaced by an electronic controller compatible with the electronic temperature control system. The temperature control system will be achieved by a temperature monitoring device in the outlet of the pulverizer at the area of the flange where the current exit damper is placed. The relationship between a damper controlled by temperature (hot air damper) and a damper controlled by pressure (cold air damper) will be integrated by a feed forward controller. This is required to anticipate changes in the flow rates of the two air streams and minimize "hunting" which could result without this "anticipatory" control.

When the pulverizer inlet valve is closed by the burner management system as described in Section C, Part 3, Paragraph C, the temperature modulating system is electrically de-energized. The hot air damper will then automatically close, blocking the flow of hot air to the pulverizer ducting. The operational speed of the hot air damper will be designed to be faster than the operational speed of pulverizer inlet valve. Thus, hot air will be prevented from travelling up through the feeder or out the cold air damper leading to the plant.

As the hot air damper closes, a pressure sensing instrument in the lower pulverizer duct will sense the increased negative pressure created by the lack of air to the pulverizer, and will open the cold air damper. Even with the pulverizer valve shut off, slight leakage from the hot air duct will be dissipated to the cold air duct, minimizing hot air exit to the surrounding area.

In operation the air preheater will supply hot air of approximately 400 degrees F to the ductwork. The temperature indicator and setpoint control mounted on the boiler main control panel will call for opening or closing of this damper. The existing dampers will open and close to admit quantities of cold air to the pulverizer to be mixed with the hotter air. The temperature probe on the outlet side will control the hot air dampers and allow for monitoring of the exit temperature of the pulverizer. As more hot air is drawn into the pulverizer to transfer heat to the coal and dry the coal, the existing dampers will close to balance the air requirements of the system. During shut-down procedures, outlined later, the setpoint controller would be turned down by the boiler operator. This would then shut-off the hot air damper and allow cold air to be drawn through the pulverizer to cool it down quickly for shut-down. The existing system does not have this capability and leads to problems of explosive potential with regards to the operation of the pulverizer.

The capability to control the exit air temperature to the pulverizer will result in superior drying capabilities for the existing installation. This should minimize coal pluggage from the pulverizer which is due to insufficient drying capacity. In addition to providing these benefits from an operation standpoint, the modification will result in substantial savings to the operation. It is believed that the current design of the system realizes an air preheat temperature of 200 degrees F. This air is used as primary air supplied to the pulverizer for drying and as secondary air to the burners for combustion. By limiting the temperature of this air to satisfy the requirements of the pulverizer, heat is lost to the stack instead of being returned to the boiler as make-up air. This is inefficient utilization of the air preheater. It must be pointed out that this condition may also exist with the use of oil as a secondary fuel for the burners. If the manual dampers are not adjusted when fuel oil is

selected, these heat losses occur. The calculations provided show that there is a potential savings of nearly 4 million BTU per hour. At costs of 3 to 5 dollars per million BTU's of heat, one can see that this is a significant number and the modification of this system could rapidly pay for itself in terms of higher utilization of existing fuels.

c. Pulverizer re-start after a burner trip:

It is reported that if the pulverizer is tripped, there is sufficient coal inside that a re-start is not possible because of clutch slippage. After a trip the pulverizer must be opened and cleaned out. The pulverizers were examined and the applicable service manuals for the pulverizers were examined to determine if there were any conclusions that could be drawn as to this type of operation.

First, it must be pointed out that this pulverizer is classified by NFPA as a low storage pulverizer. There is supposed to be a minimal amount of coal in the pulverizer as compared to other models of pulverizers. The pulverizer receives lumps of coal and in the first stage of pulverization, breaks these larger chunks into smaller particles where they are impelled by the rotary motion of the hammers into a second chamber where the small chunks are then ground into a fine powder by impinging them upon stationary pegs. There are many factors which influence the path of an individual particle of coal once it enters the pulverizer. In normal operation the chunks hit an impact hammer which propels the chunks into the top portion of the pulverizer. The impact of the chunks hitting these surfaces causes the chunks to shatter into smaller particles. The movement of the air inside the pulverizer then propels these chunks into the second chamber of the

pulverizer where there is further impact between stationary pegs and movable pegs connected to the rotor of the pulverizer. It is possible for a chunk to drop through the exit chute and travel directly to the bottom of the pulverizer without touching any impact hammers. This chunk would travel through the hammer and remain in the bottom portion of the pulverizer. However, the original design speed of the pulverizer of approximately 1200 RPM minimizes the potential of this occurance.

If a chunk of coal is of such a nature that it is not friable, the impact hammer will propel the chunk to the top of the pulverizer. It will continue to travel round and round in the first section of the pulverizer until it is able to escape between the impact hammers. Rejection of hard particles is a requirement for proper operation of the pulverizer since these particles can cause damage to the stationary and moving pegs of the pulverizer. Hardness of the coal could have changed over the period of time which the pulverizer has been in use at the facility. The only way to verify this condition is to take a chemical and physical analysis of the particles remaining at the bottom of the pulverizer after extended operation. The presence of hard particles would indicate a problem of purchasing of coal to a specification that would allow for proper pulverizer operation. The quantity that we are referring to is extremely small in a total coal sample.

A quantity of 200 lbs. of particles are reported in the bottom of the pulverizer. If the pulverizer remains in operation for 4 hours at 5,000 lbs per hour this would represent less than 1 % of the total with this high hardness. If this were to be extended to a 40 hour time period, the material would constitute less than 0.1% of the total material handled through the pulverizer.

Due to the metallurgical nature of coal this might be a reasonable number. Therefore, a design of a removable box in the pulverizer might be required. This removable box would allow for cleanout of the pulverizer in a time period of thirty seconds or less. A new

empty box could be inserted where the old box was replaced and this would not interfere with the operation of the pulverizer and could in fact be done while the pulverizer was in operation. This is possible because the pulverizer has a large negative pressure associated with it during its normal operation. Air would be sucked into the pulverizer through the open cleanout gauge during operation. Thus, no large quantities of dust would be generated by the operation of cleaning out the pulverizer.

When the door is opened, cool air will be drawn in. The temperature controller will sense a drop in temperature and will open the hot air damper more. The pressure controller will close the cold air damper since the pulverizer duct will go less negative, as air enters the pulverizer through the open door. The size of the door will limit the amount of air into the pulverizer through the door. In this manner, the system air flow will remain in balance.

During discussions with the operators at the facility, it appeared that instances of coal build-up in the pulverizer has diminished over the last few months. This could be as a result of some modification made to the electrical system by the facilities engineers. When the boiler was converted to primary coal with secondary oil in early 1979 a design defect was discovered. The original design called for a coal auxiliary control relay contact for each burner control circuitry, to be placed parallel in the motor starter circuitry of the feeder. When both feeders were in operation, these parallel sets of relay contacts did not stop the feeder upon loss of flame in the boiler. The electrical circuitry would have kept the feeder on and supplying coal to the pulverizer which could have been stopped by the boiler operator. This condition has since been rectified and the boiler plant is now currently working on a system where feeder and pulverizer No. 1 is supplying coal only to burner No. 1, similarily for No. 2. There will be a further discussion of the burner safety controls as part of Section C The Electrical Interlock Controls.

d. Fire Protection

The principal means for controlling fires in the pulverizer will be through the temperature control system outlined in paragraph b of this section. The temperature monitoring devices outlined in paragraph b would be used to detect the presence of a fire in the pulverizer. Thus the setpoint controller should be designed with a high limit alarm and annunicator to instruct the boiler operator of a fire in the pulverizer.

The first action required by the boiler operator would be to lower the temperature setpoint and stop the coal feed. This immediately prevents more fuel from being added to the fire and begins to minimize the temperature of the fire by bringing in cold air.

If these activities do not control the fire, then further measures are required. These measures involve complete inerting of the pulverizer per NFPA 85F Section 3-2.4. When initial attempts fail to limit the fire, complete shutdown of the pulverizer is required and a total inerting is necessary. This can best be accomplished by placing a permanent one inch, 5 psig steam line with appropriate valving directly into the pulverizer. The introduction of steam into the one inch line should be controlled by valving suitably located for fighting a fire. Installation of this line would meet the requirement of NFPA 85 Section 2-4.1 and 3-2.4 and is hereby recommended by this study.

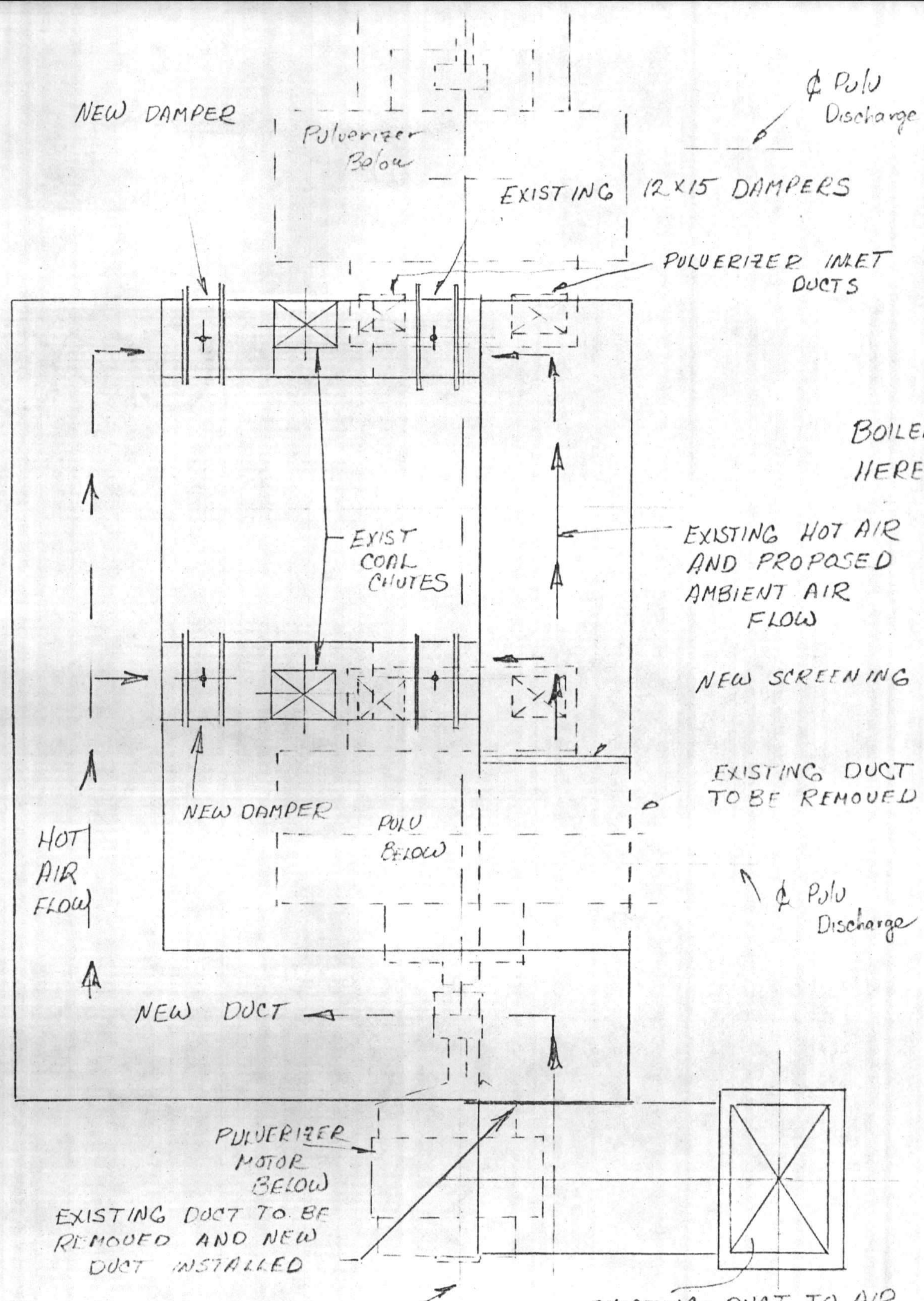
e. Testing of air delivery

NFPA 85F Paragraph 2-3.3 requires that testing during initial start-up shall be performed to verify that pipe velocities are adequate. To the best the writer's knowledge no testing has ever been performed on these pulverizers to insure that the outlet air velocities are sufficient to carry the fuel to the burners. Over a long period of time the fan characteristics may have changed and

it is good practice to verify that the velocities are adequate to transport the fuel. Again these conditions are not mandatory but conservative operational practice of the boiler plant should verify that transport velocities are adequate. Coal sampling ports are installed on the pipes to allow for this type of testing. These ports were last opened when the electrostatic precipitator was added to the system. The test performed at that time involved sampling activities regarding the fineness of the coal delivered to the burners and did not involve calculation of velocities present in the pipes.

f. Full speed switch of pulverizer

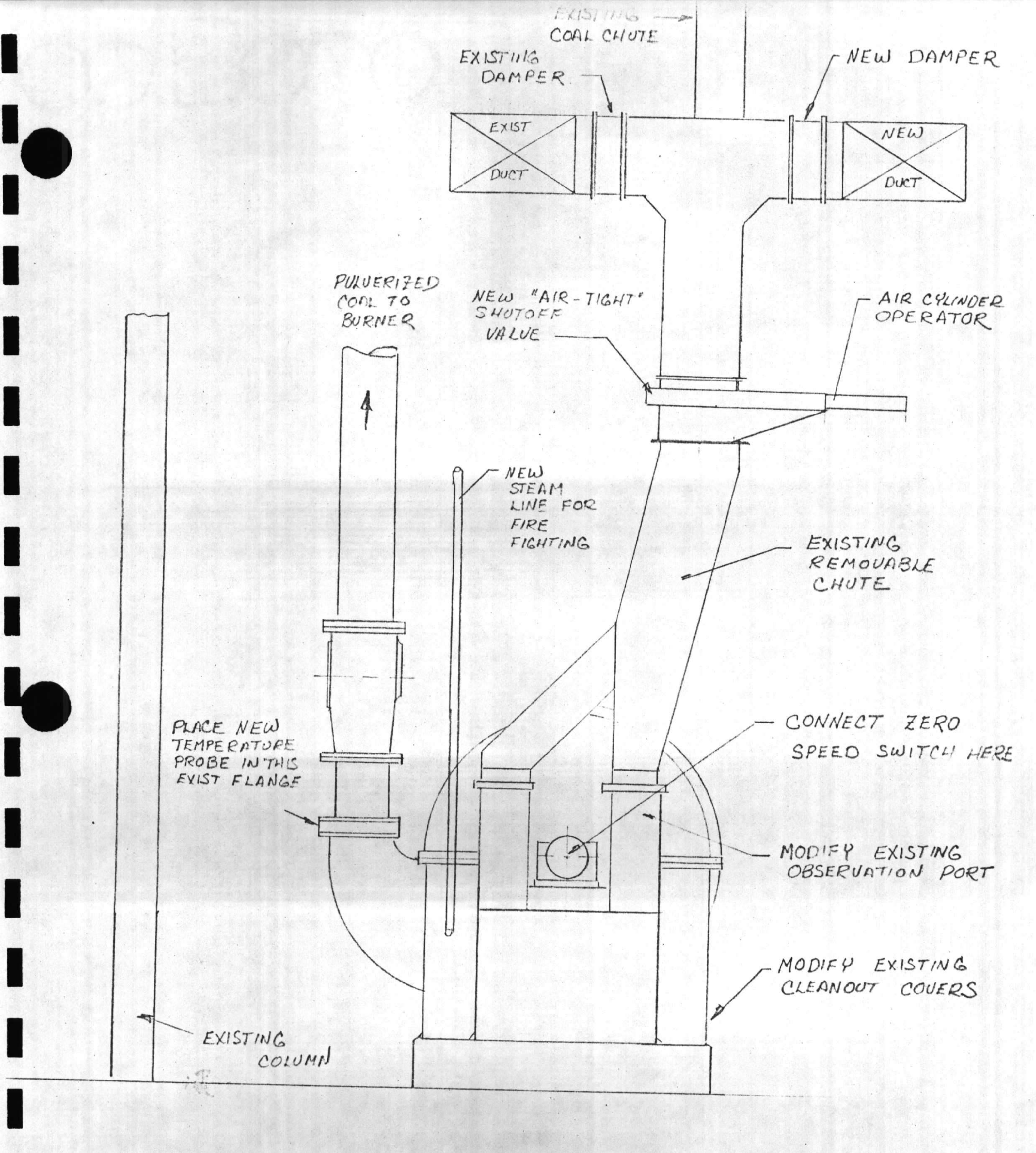
NFPA 85E Section 633 "Mandatory sequential starting interlocks" calls for the pulverizer to start before the raw coal feeder. At this particular installation there is a significant time lag between the starting of the pulverizer and the time in which material can be pulverized. Observation indicated at least one minute for the pulverizer to accelerate up to its no-load speed of close to 1200 RPM. To meet the NFPA requirements, a zero speed switch set to operate on the pulverizer above 1,000 RPM should be added to the pulverizer. This speed switch could then signal the electric controls, which are discussed elsewhere, to allow for coal feeding to begin. If this is not accomplished, the pulverizer may potentially bog down due to the large amount of coal that can be added during this start-up condition. This switch is shown in the sketches following this presentation.



PLAN VIEW
JUST BELOW OPERATING
FLOOR BEAMS

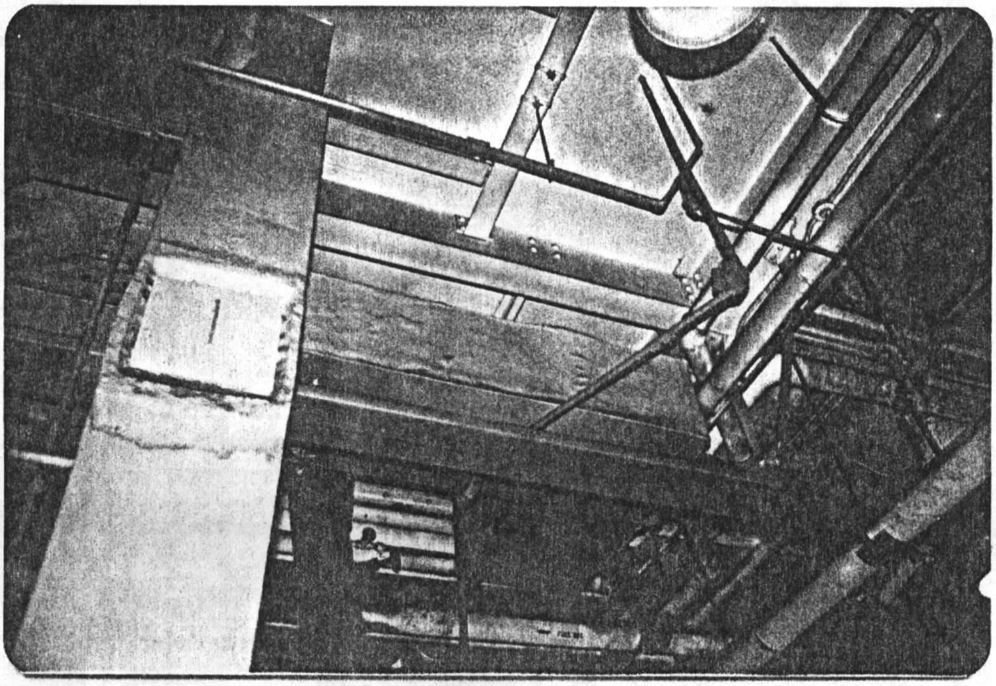
SKETCH OF NEW DUCT ARRANGEMENT

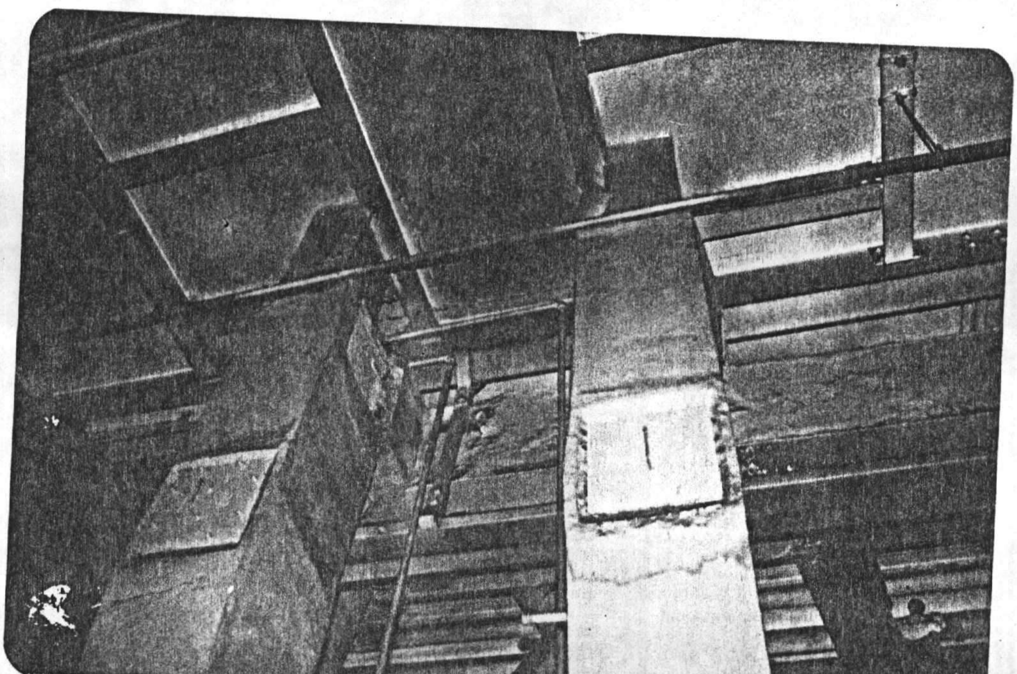
SCALE 1/2" = 1'-0"



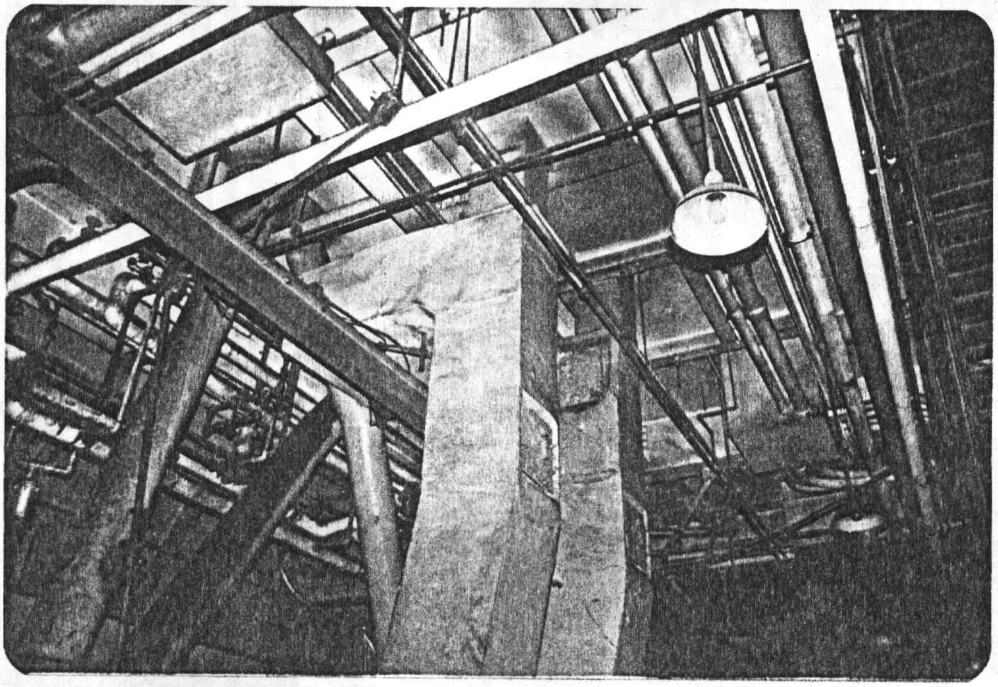
ELEVATION AT COAL PULVERIZER

SCALE 1/2" = 1'-0"



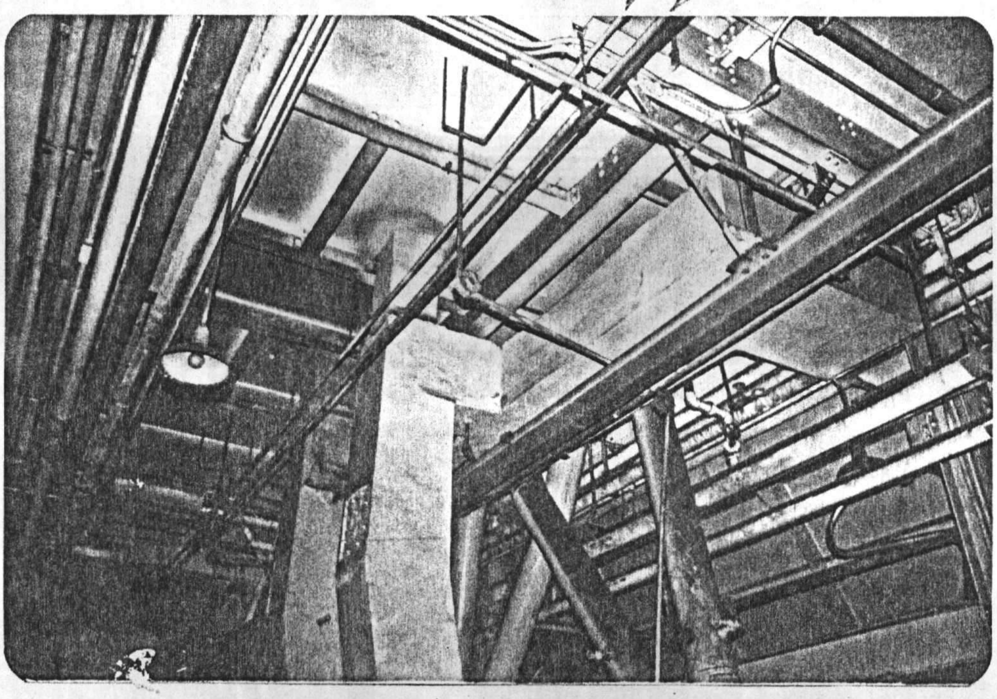


EXISTING PULVERIZER DUCTWORK

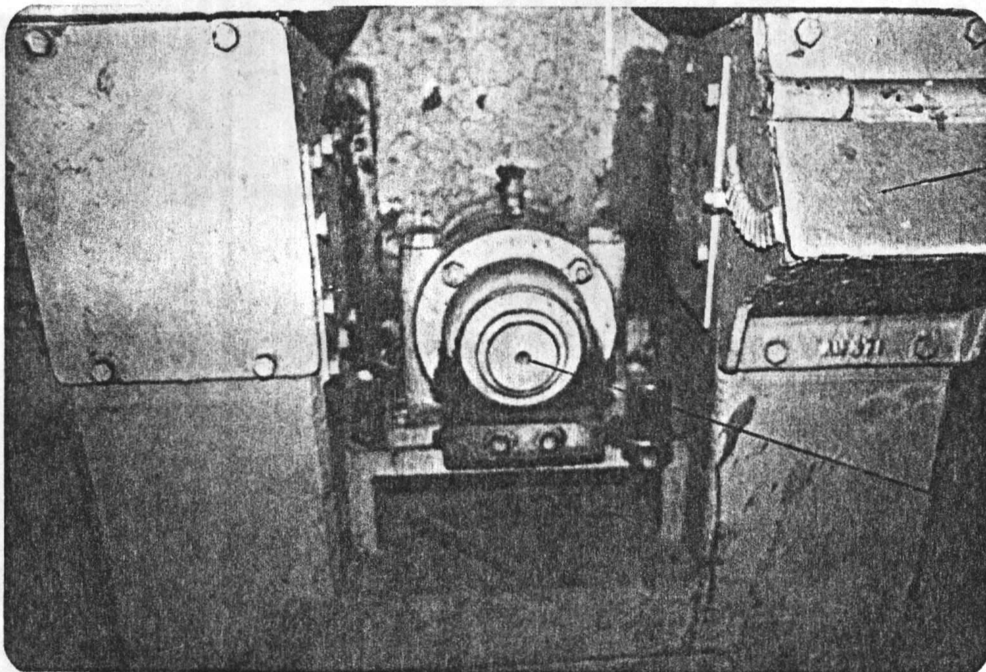


THIS IS THE MOST
CROWDED SPOT
AROUND NEW
DUCT PROPOSED
AREA OF ALL
4 BOILERS

COMPRESSED AIR LINE
CHEMICAL FEED LINES

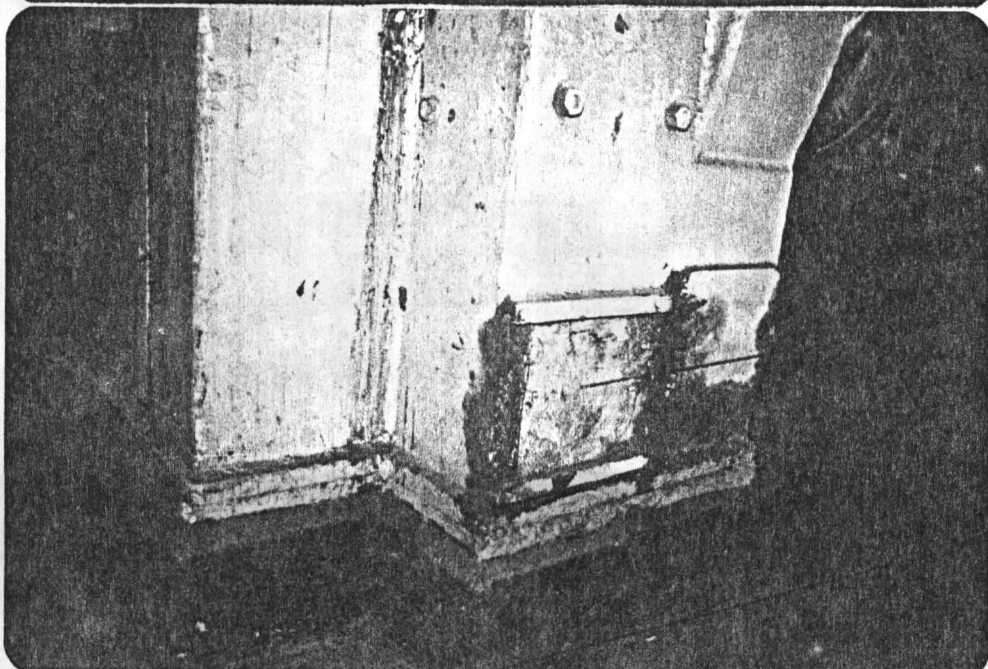


EXISTING PULVERIZER DUCT WORK



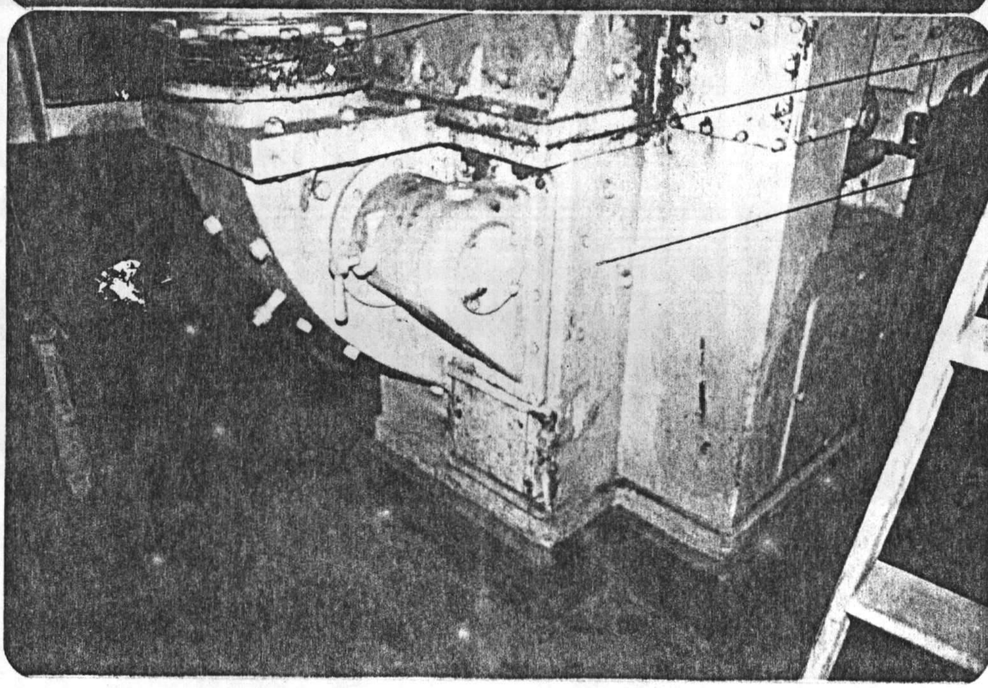
MODIFY INSPECTION DOOR FOR BETTER SEALING

ATTACH ZERO SPEED SWITCH TO PULVERIZER MAIN SHAFT



MODIFY CLEANOUT DOORS FOR BETTER SEALING

INSTALL TEMP PROBE IN THIS FLANGE OUT OF COAL & AIR STREAM



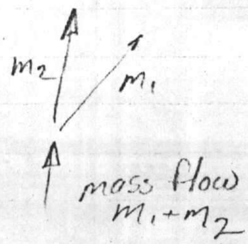
METAL GASKET FOR JOINT

INSTALL STEAM LINE HERE (VALUED FOR FIRE FIGHTING)

Hartrampf Powell Incorporated	Job Camp Le Jeune
Consulting Engineers, Atlanta Georgia 30328	Name Air Flow Thru Pulverizer
	Date 11/18/80 — Sheet 1 of 9

Air Flow Thru Pulverizer

Transport Velocity ≈ 3,500 - 4000 ft/min
Operation Thru 2 pipes can take place



Mass flow m_2 must be a minimum of 3500 ft/min
Likewise for m_1

Pipe Sizes used = 10" Sch 40

ID of pipe = 10.02   Area = 78.85 in^2 = .5476 ft^2

Flow Rate = AV = .5476(3500) = 1916.6 acfm

Total Output of Mill = 2(1916.6) = 3833.2 acfm

Output Temperature of Mill Max = 220°F

From Riley Actual Output ≈ 4000 acfm
Maximum Static Head ≈ 20" H_2O

Velocity of intake duct = 4000 cfm / Area = 3200 ft/min

1) Assume 1 pulverizer handling 50% of load
Air Flow = 4000 cfm   Coal Temp = 70°F
Coal Flow ≈ 5000 lbs/hr
West Virginia Coal with inherent moisture content of 4% and total moisture of 10% net

2) Action of hot air entering pulverizer is to remove moisture from coal and heat coal to exit temperature
Actual heat lost is 6% by weight of coal

h_f moisture @ 200 = 167.99   Diff ≈ 130 BTU/lb
70 = 38.04

let cp ≈ Specific heat of coal ≈ .1 BTU/lbm °F

Heat transferred to coal (dry basis)

= 5000 (1-.16) (.1) (200-70) = 54,600 BTU/hr

Heat transferred to water
= 5000 lb (.06) (1) (200-70) = 39,000 BTU/hr

Total Heat transferred = 93600 BTU/hr

Enthalpy Difference in cooling air from 400 to 200 & transferring heat to coal & water vapor

h = 206.46 - 157.92 = 48.54 BTU/lb

Flow rate of 400°F air required = 93600/48.54 = 1928 lbs/hr

Density of air @ 400°F = 25.4(400+460)/1000 = 21.84 ft³/lb

Volume Req'd = 42,115 ft³/hr ≈ 702 cfm

+ Additional Volume Req'd to heat ambient air to 200°F

From previous calc 702 cfm of air @ 400°F
is required to dry coal

Heat req'd for heating ambient air to 200°F

Specific volume @ 200°F = 25.4(200+460)/1000 = 16.764 ft³/lb

For 4000 cfm @ 200° mass flow = $\frac{4000\ ft^3}{MIN} \times \frac{lb}{16.764} = 238.607$ lb/MIN

Mass flow of 400°F air drying of coal = $\frac{1928\ lb}{hr} \times \frac{hr}{60\ min} = 32.133\ \frac{lb}{MIN}$ (used for drying)

Heat balance for Air Heating

$x\ \frac{lb}{MIN}$ @ 80° (129.06) + (y − 32.133) 206.46 = 238.6 $\frac{lb}{MIN}$ × 157.92

x + y = 238.6

129.06 x + 206.46y − 6634.18 = 37679.7
129.06 x + 206.46 y = 44313.9
129.06 x + 129.06 y = 30793.72
77.4 y = 13520.18
y = 174.68 lb/MIN

Total flow of 400°F air = $21.84\ \frac{ft^3}{lb} \times 174.68\ \frac{lb}{MIN} = 3815\ \frac{ft^3}{MIN}$

Total flow of 80°F air = 63.92 lb/MIN

Density of 80° Air = $25.4\left(\frac{80+460}{1000}\right) = 13.716$ ft³/lb

Volume flow = $13.716\ \frac{ft^3}{lb} \times 63.92\ \frac{lb}{MIN} = 876.72$ cfm

Damper & Other Source Leakage of Tertiary Air

Total Air Flow @ 80°F = 876 cfm with mill suction of .7 in H_2O pressure

$Q = 1098\, A\sqrt{Hw\,v}$

where
Q = flow rate
A = Area sq ft
Hw = pressure V = specific volume

or $A = Q / 1098\sqrt{Hw\,v}$

$= 876\text{ cfm} / 1098\sqrt{.7\,(13.716)}$

$= .2575\text{ ft}^2 = 37\text{ in}^2$

Area of coal chute is larger than this, so feeder should be kept reasonably air tight

Window Area was about 4×4 in or 16 in^2 so it must be kept closed

This leaves total of 21 in^2 available for leakage at pulverizer, chutes & damper.

Damper 12×15 Leakage along 15" height ≈ .25
total area = 7.50 in^2

Remainder = 13.50 in^2 along 12" sides

Opening = .56 in maximum

1) Assume 24,000 scfm - combustion air required @ 100% capacity - Flue Gas Mass Flow ≈ 122,000 lbs/hr
Existing flue gas exit from boiler @ 550 °F
Existing air preheater exit temp @ 200°F
Air req'd per pulverizer = 4000 cfm. @ 200 °F

2) Existing system limits air (primary & secondary) to 200°F

3) Modification assumes system can extract more heat from flue gas and raise exit temperature to 400°F

4) Net heat gain with no other modification than pulverizer ducting, damper and temperature recorder will be

Flow × Δt - 24,000 scfm @ 200° ΔT

Specific volume @ 80° F = 25.4 (80+460)/1000
= 13.716 ft^3/lb

Mass flow @ 24,000 scfm = $\frac{24000\ ft^3}{MIN} \times \frac{lb}{13.716\ ft^3}$ ≈ 1750 $\frac{lbs}{MIN}$ (air + water vapor)

Enthalpy Air @ 80°F = 129.06 BTU/lb
200 = 157.92
400 = 206.46

Enthalpy of Flue Gas 0% moisture = .2517 $\frac{BTU}{lb}$ × F° − 21.16

Same flow rate of 400°F air is required to go to pulverizer as required if temp is 200°F

But remainder of flow goes to secondary air

Currently 1750 lbs/MIN of 80°F is introduced to preheater

Heat transfer if exit temp = 200°F = (157.92 − 129.06) 1750 lbs/MIN

= 50,505 BTU/MIN = 3,030,300 BTU/hr

Current setting allows for large quantity to bypass air heater

Heat transfer if exit temp = 400°F = (206.46 − 129.06) 1750 lbs/MIN

= 135,450 BTU/MIN = 8,127,000 BTU/hr

Effect on flue gas exit temperature

Heat loss by flue gas = 8,127,000 BTU/hr with flow of 122,000 lbs/hr

Heat loss flue gas = 66.61 BTU/lb

Temperature loss = $\frac{66.61 \text{ BTU/lb}}{.2517 \text{ BTU/lb°F}}$ = 264.66

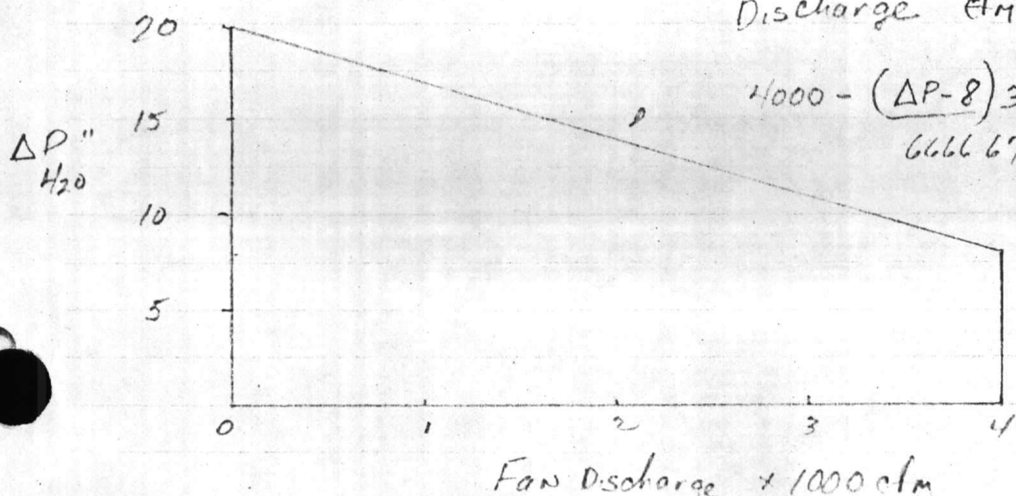
Flue gas exit = 285° slightly low − 325 recommended

Full flow can not be established at 400°F but say 85% of heat transfer

New Rate = .85(8,127,000) Old rate = 3,030,300

Net Savings <u>3,877,650 BTU's/Hr per boiler</u>

The air fan in the pulverizer is capable of producing up to 20" H_2O pressure differential. Since the inlet will be essentially blocked off and pulverizer will go highly negative. There will be leakage into pulverizer which will be discharged by action of fan. Calculate this flow and area size for the suction.



Discharge cfm

Fan Curve Pulverizer

$4000 - (\Delta P - 8)\,333.33$

$6666.67 - 333.33\,\Delta P$

Examine $\Delta P = 19"$ Discharge $= 333.33$ cfm

$Q = 1098\, A \sqrt{H_w v}$ $\qquad v_{air}$ @ 200 $= 16.764\ ft^3/lb$

$\therefore A = Q / 1098 \sqrt{19(16.764}$
$= .01701\ ft^2 = 2.449\ in^2$

Total leakage should be able to be brought to that level by careful design and attention to leakage around the pulverizer.

This will require modification of access & clean out covers to provide better sealing

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Consulting Engineers, Atlanta Georgia 30328	Name: Coal Discharge @ Shut Off
	Date: 10/21/80 — Sheet 8 of 9

Equation

fuel flow = .000625 × (primary air$_{cfm}$)^2

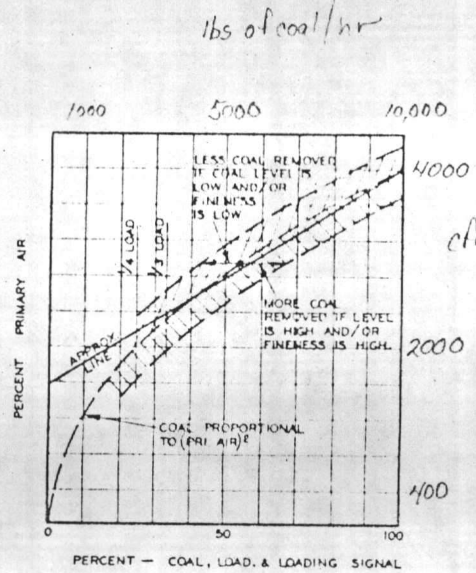


FIG. 17

EFFECT OF PRIMARY AIR, FINENESS AND LEVEL ON THE RATE COAL IS DELIVERED FROM A PULVERIZER.

Chart taken from "A RELIABLE AND ACCURATE FEEDING SYSTEM IS THE MAJOR COMPONENT OF GOOD COMBUSTION CONTROL" by Arthur L. Bennett and Ralph Hardgrove

Institution of Engineers and Institute of Fuels Australia Aug, 1972

Under conditions of 19 in H_2O and 333.33 cfm primary air

Coal flow = .000625 lb/hr × $(333.33)^2$

= 69.44 lbs/hr = 1.157 lbs/MIN

Explosive Mixture - Pulverized Coal = .003 #/ft^3

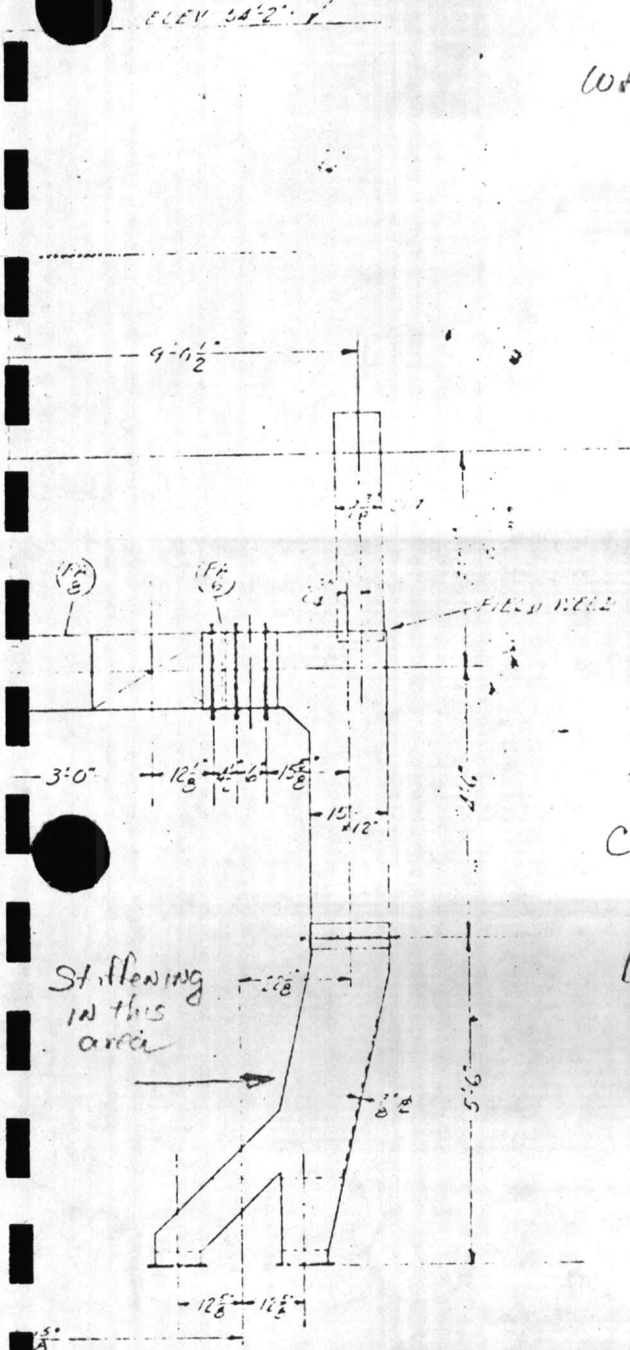
Volume of Boiler ≈ 6650 ft^3

Explosive Mixture ≈ 20 lbs of coal

Time Available to take corrective action (purge of boiler)

= 20#/1.157 lb/min = 17 MINUTES

Adequate!



Material: 3/8" thick mild steel plate

Maximum bending area = 15 in wide!

$\Delta P = 20" \div 104\ \#/ft^2 = .72\ psi$

With span a fixed
b supported

$b = 15 \quad a = 66$

$a = 15/66$

$$M_{bc} = \frac{.125\, w b^2}{1 + .8a^2 + 6a^4}$$

$$= \frac{392}{1.06}$$

$= 370$ in lb/in of width

$$\sigma = M/z$$

$$= \frac{370(6)}{1(.375)^2}$$

$= 15,820$ Okay!

Deflection $= C(1-\mu^2)\, w b^4 / Et^3$

$= C\ (7.68)$

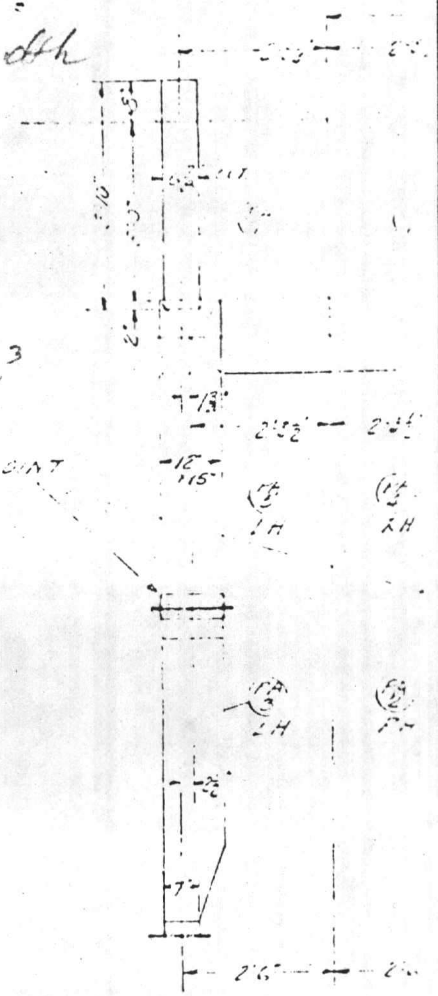
$C = .16 / 1 + a^2 + 5a^4$

$= .15$

Deflection = 1.15 inches

Not Acceptable!

Will require stiffening



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B. IGNITOR ANALYSIS

1. REQUIREMENTS:

According to the National Fire Codes published by the NFPA National Fire Protection Association the ignitor to be used for pulverized coal must be either a class 1 or class 2. Class 1 is a continuous ignitor, that is lit whenever coal is being fired or being prepared to be fired. Class 2 is an intermittent ignitor which can be operated at any time for a given period of time. The existing ignitors were estimated to be capable of approximately 1% of the heating load which is not sufficient to qualify it as a Class 2 ignitor. For the purposes of the Riley boilers at Camp Lejeune, an intermittent ignitor will be chosen. This selection is dictated by the existing controls but it will be sized so that it can be operated as a Class 1 continuous ignitor. A Class 1 ignitor must be in excess of 10% of the full load of the burners; an intermittent or class 2 ignitor is generally between 4 and 10% of a full load of a burner. In our particular case each burner is capable of taking half the load of the boiler which can be a maximum of 120,000 lbs. per hour for the boiler and therefore 60,000 lbs. for each burner. The ignitor will be sized at about 10% of that which is 6 million BTU's per hour.

2. DESCRIPTION:

The ignitor will be located in each burner in replacement of the existing propane ignitor. The existing ignitor screws into a 2-1/2" pipe nipple welded into the burner. This nipple shall be replaced with a 4" nipple if a Peabody ignitor is selected. Because of the limited storage capacity of the two 1,000 gallon propane tanks at the plant, a high energy spark/No. 6 oil ignitor will be chosen. Choice of this ignitor will eliminate the need for additional storage and piping to the building propane system. No. 6 oil which is presently being pumped to the front of the boiler will be supplied from that line and be run to the new ignitor.

Calculation sheets at the end of this section address the amount of propane required based on past usage and projected usage. To maintain an adequate propane flow and capacity for operation of all ignitors simultaneously a 30,000 gallon tank, a vaporizer, plus piping and control valves will be required. If natural gas were available to the plant, the additional capital cost would be the piping and controls only. No. 6 fuel-oil is recommended for the new ignitor because of the lower initial cost of installation, the present availability of the fuel at the building and the projected fuel costs based on decontrol of natural gas. The present cost of natural gas is approximately equal to the cost of No. 6 fuel-oil on a cost per BTU basis.

The atomizing requirement for this new ignitor will be either steam or air. The attached calculation sheet shows the requirements for steam and air for atomizing. Oil from the present pump and heater set to the burners is supplied between 190 degrees and 200 degrees F. This temperature will be sufficient for use of the ignitors although a temperature of 220 - 230° F. is preferred for No. 6 fuel-oil. The pump and heater set is listed as a cost option because it is not required with the present equipment available in the plant.

The ignitor should also be supplied with purging valves so that upon shut-off of the ignitor, the oil valves will shut and the air atomizing valves will open such that the air shall go through the oil supply line into the ignitor following the path of oil. This will completely purge the ignitor. The valves will automatically operate and controls will be supplied with the ignitor such that this will be an automatic function. Also supplied with the ignitor is the equipment necessary to have it operate within the NFPA requirements with only the proper signals to turn on and shut it off coming from the master controls.

The ignitor itself will have an output of approximately 6 million BTU's but upon operation it may be determined that a larger or smaller output will be required which can easily be done through adjustment of the ignitor tip or adjustment of the pressure. Air for atomizing being of a constant pressure and a low volume may be easily supplied by the existing compressors. Therefore the entire igniter system will use existing utilities rather than installing any new ones. Steam atomizing will require a constant pressure of between 80 - 100 psig. Piping from a source of steam will require a pressure regulating valve. The piping should be insulated. It is recommended that both steam and air be piped up for atomization. The alternative of two atomizing fluids give the operation greater flexibility.

If No. 6 fuel oil fired ignitors are installed, the boiler could be operated with coal as the main fuel even when the coal is wet. Presently the plant must operate on the more expensive No. 6 fuel oil when the coal is wet, but oil fired ignitors will carry 10% of this load on oil and the remainder of the load could be carried on coal. This is also the advantage of having Class I or Class II ignitor which can be continuously fired.

The option is still available to go to propane ignition or natural gas ignition but all those choices would involve a higher initial cost to install those utilities to the plant as well as greater operating cost as the cost of propane and natural gas rise above the cost of No. 6 fuel-oil on a dollars per BTU basis. The cost of a propane system is given as a cost additive in the estimate.

The ignitor control package will retract or insert the high energy spark electrode upon the proper master control signals to start or shutdown the ignitor. Normally the electrode is kept on for a period of ten to fifteen seconds to allow the fuel to arrive at the burner tip. The electrode is shut-down and retracted after this time.

When ordering the new ignitor it can be sized to any length. The length chosen should be equivalent to the existing ignitor length which is approximately 27 inches. This locates it at an angle to the main coal burner and at approximately an inch or two beyond of the end of the coal pipe.

3. OPERATION:

The ignitor is operated for a period of time set on the control timer, ICIT. Presently this timer has a range of 0 to 300 seconds but should be changed to 0 - 30 minutes with changes suggested in this study. At the expiration of this timer the ignitor will be shut down automatically and the controls inherent in the ignitor will purge it. The existing controls are such that the ignitor can be re-lit at anytime without a purge if there is a flame in the boiler at either burner. If all flame is lost, the boiler must go through a purge. The new ignitor has its own purge system and control which is additional to the boiler purge.

In addition to the control changes suggested in the study, modification should be made to the purge circuitry. The existing circuitry allows for the bypass of oil supervisory limit switches when firing on coal. These limits were bypassed because of propane ignition.

If oil ignition is selected, these limits should not be bypassed and rewiring will be required. These changes will meet NFPA requirements for an assured fuel supply before introducing an ignition spark.

The ignitor automizing pressure will require a constant 80 - 100 psig and the oil pressure can vary from approximately 100 to 300 psig. The pressure and therefore the flow will determine the BTU output of the

ignitor. Oil, No. 6 fuel-oil especially, should be pumped into the ignitor between 200 and 220 degrees F. This should be attainable with the present pump and heater set. The controls at present do not close the dampers leading from the air duct to the windbox so that there is sufficient combustion air for the ignitors to operation with the present boiler controls. At one time the controls were designed to operate such that the dampers would shut off when ignition was to be made, but it has been found through experience that reduction of the air flow is not required. The logic of the existing controls is not clear but its present operating sequence is workable.

I IGNITOR SIZING

CLASS II INGNITOR SHALL BE 4% - 10% OF LOAD

THEREFORE ÷

① FULL LOAD ON BOILER - 100,000 LBS/HR

② ENTHALPY AT 150 PSIG SAT STM - 1194 BTU/LB

ENTHALPY AT 150 PSIG, 150°F 118 BTU/LB

③ HEAT INPUT REQUIRED

$$\begin{array}{r} 1194 \\ -118 \\ \hline 1076 \end{array}$$

1076 BTU/LB × 100,000 LBS/HR = 107,600,000 BTU/HR

HEAT INPUT PER BURNER

$$\frac{107,600,000 \text{ BTU/HR}}{2} = 53,800,000 \text{ BTU/HR}$$

10% IGNITOR IS THEREFORE 5,380,000 BTU/HR CAPACITY

SINCE BOILER IS SPECIFIED TO BE CAPABLE OF 120,000 LBS/HR IGNITOR SIZE CAN BE AS MUCH AS 6,000,000 BTU/HR.

OIL REQUIRED PER IGNITOR -

FOR NO. 6 OIL 150,000 BTU/gallon

6,000,000 BTU/HR ÷ 150,000 BTU/gallon = 40 gallons/HR

= .66 gallons/MIN

SINCE THE OIL FLOW IS SMALL 1/2" PIPE IS SUFFICIENT.

#6 OIL IS 8.45 LB/gal   8.45 × .66 = 5.57 LBS/MIN OF OIL

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Job CAMP LEJEUNE	
Name STUDY FOR BOILER OUTPUT COAL FEED AND ASSOCIATED PULVERIZ...	
Date 11/25/80	Sheet — of 4

II ATOMIZING
A STEAM

.03 LBS OF STEAM PER LB OF OIL
.03 × 5.57 = .1671 LBS/MIN OR 10.026 LBS/HR

B. AIR

1.5 X STEAM REQD = (1.5) .1671 = .25 LBS/MIN OR 15.04 LB/HR

VOLUME OF AIR REQ'D: $25.4\left(\frac{80^\circ + 460^\circ}{1000}\right) .25 = 3.43$ cfm

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Job	CAMP LEJEUNE
Name	STUDY FOR BURNER CONTROL COAL FEED AND ASSOCIATED PULVERIZER
Date	Sheet 3 of 4

Evaluation of Propane system for ignitors

PROPANE USAGE IN AVERAGE MONTH:

155 THERMS ÷ .915 GALLONS/THERM = 170 GALLONS

(BECAUSE OF UNUSUAL OPERATING CONDITIONS LAST YEAR THE AVERAGE PROPANE USAGE WAS

253 THERMS FROM FEB '80 TO JAN '81

253 THERM ÷ .915 GALLONS/THERM = 277 GALLONS

NEW IGNITORS WOULD HAVE 10 TIMES THE CAPACITY OF THE EXISTING IGNITORS SO THE AVERAGE USAGE PER MONTH WOULD BE

170 × 10 = 1700 gallons/MONTH

THE 2 EXISTING 1000 gallon tanks in the YARD WOULD SUFFICE FOR AN AVERAGE MONTH, BUT FOR THE WORST MONTH 593 GALLONS WERE USED.

593 × 10 = 5930

(5930 gallons ÷ 2000 gallons) ÷ 31 DAYS/MONTH = 10 DAYS

THE STORAGE AT PRESENT WOULD LAST ONLY 10 DAYS.

ONE IGNITOR WOULD BURN 6,000,000 BTU/HR OR

$$\frac{6{,}000{,}000 \text{ BTU}}{91500 \text{ BTU/gallon}} = 65.6 \text{ GALLONS/HR/IGNITOR}$$

IF ALL 4 BOILER WERE TO OPERATE BOTH IGNITORS FOR WARM-UP OR BECAUSE OF WET COAL THE PROPANE CONSUMPTION WOULD BE:

65.6 × 8 = 524.8 GALLONS/HR

524.8 × 24 = 12595 GALLON/24 HOUR DAY

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	Name STUDY FOR BURNER CONTROL	
	COAL FEED AND ASSOCIATED PULVERIZER	
	Date	Sheet 4 of 4

WITH ALL IGNITORS BURNING THE TOTAL STORAGE OF PROPANE WITH 2-1000 GALLON TANKS WOULD LAST ONLY 3.8 HOURS

THIS CONDITION IS NOT ACCEPTABLE FOR EMERGENCY CONDITIONS.

C. ELECTRICAL INTERLOCK CONTROLS

1. Existing Controls:

The most distinctive aspect about the existing burner control system is its inability to handle cross-firing situations. The easiest explanation of cross-firing is when feeder No. 1 brings material to pulverizer No.1 which in turn then blows the coal to burner No. 2. This situation can occur by the manual movement of the coal valves situated at the output of each pulverizer and the input to each burner. The design modifications done in December of 1978 converting the plant to primary coal did not address this problem of cross firing adequately. These modifications allowed both feeders to be started automatically with a single burner control and did not remove power from a feeder with a loss of flame if another feeder was operational. The coal auxiliary control relays for both burners were wired in parallel to each feeder starter. This hazardous situation was corrected by the Public Work Engineers, but the drawings still reflect the original design.. It is unclear as to the degree of importance that the original design contributed to the reports of pulverizers filling up with coal. With the early design, such an event was likely to have occurred frequently.

Because of the previous conditions associated with cross-firing it is believed that the facility has been ordered only to use the pulverizer, feeder and burners with the same number. This eliminates any potential hazard connected with cross-firing. However the ability to cross-fire still exists at the boiler plant.

The pulverizer is controlled by interlocking it with the induced draft fan auxilary contact and a manual switch at the main boiler control panel. The feeder is interlocked with the respective pulverizer and burner control. Because there are no interlocks between the pulverizer and burner control, the coal can be pumped in to the boiler without burner protection. Existing practice has been that the pulverizer would be cleared of coal before turning on and starting up a normal firing operation. This leads to the potential for human error to cause an explosive condition.

The existing drawing of the schematic diagram of the boiler safety controls does not reflect the actual wiring of the controls. One can see from the drawing that an apparent unsafe start-up and shutdown condition with coal could occur. This is not the case. Normally open and normally closed contacts 1CACR, in parallel, connecting the two flame scanners to terminal 1 and L of the fireye control have been replaced by the same sense contacts of 1CIT which is the coal ignition timer. During the time this timer is operating following ignition, the flame scanner is looking at the flame of the ignitor rather than the coal flame.

Thus when starting a boiler on coal, the flame scanner does not monitor the coal flame, which is unstable at startup, but looks only at the ignitor until the coal ignition timer "times out". Likwise when shutting down a boiler, the operator would bring in the ignitor, then shut off the coal feed and let the ignitor shut-off after a period of time to achieve shut-down. These operations are safe if, and only if, the ignitor is Class 2. The existing ignitor is Class 3 so, the existing controls are unsafe in that incomplete combustion can take place with such a small ignitor.

2. ELECTRICAL INTERLOCK CONTROLS REQUIRED PER NFPA:

NFPA specifically addresses the problem of start-up, normal operation and shut-down of pulverizer systems. The reader is again requested to thoroughly review the two applicable standards 85E and 85F (See Appendix A & B) for operation of pulverizers when firing coal in multiple burner boiler operation. To simplify the requirements and seperate them in the various areas, the following excerpts are important:

a) Startup:
Standard 85E Section 2621 Paragraph G requires that the pulverizer and burner system function as a unit so that starting of the pulverizer is integrated with the light off of all burners associated with it. This is the problem of cross firing of the boilers which will be addressed in subsequent paragraphs and in Section D of this report.

Standard 85E Section 522 outlines the starting sequence. The starting sequence is as follows a) start induced draft fans b) start forced draft fans c) purge boiler with all the burner registers open to the light-off position. d) adjust airflow rate to purge air flow. e) regenerative air heaters shall be continued in service during the start up period. f) open ignition fuel supply valve. g) start ignitors for all burners served by the pulverizer. h) with coal feeder off, open all gates between the coal bunker and pulverizer and make sure that coal is available to the feeder. i) after ignitors are established, start the pulverizer. j) start the feeder at a predetermined setting. k) check main burner for ignition l) slowly adjust air registers to their normal operating position. m) before starting another pulverizer, check to see that boiler requirements are adequate to insure that minimum air and coal feed to the boiler is exceeded. n) follow the same procedure for place additional pulverizers into service.

The same starting procedures are referred to in Standard 85F Paragraph 3-3.1.1. The specific requirements are stated as follows: The starting sequence shall be as follows: a) start-up all necessary combustion system equipment such as fans, ignitors, etc. required in proper sequence. b) open cold or tempering air damper. c) start primary air fan or exhauster if driven seperately from the pulverizer. d) open primary air flow control damper to a predetermined setting which is at least sufficient to provide minimum burner line velocity. e) open burner line valves, if any, on the pulverizer to be started. f) start pulverizer. g) start raw fuel feeder. h) place pulverizer outlet temperature control, primary airflow control, and raw fuel feed control on automatic.

b) Normal Operation:

Normal operation is addressed by Standard 85E Section 53. This Section can be found at the end of this section "ELECTRICAL INTERLOCK CONTROLS.

c) Normal Shutdown:

Normal and emergency shutdowns are covered by NFPA 85E Section 54, 55, and 56 the summary of these Standards is as follows:

(1) Take combustion control for normal on-line use out of service and place in manual mode.

(2) Start ignitors after verifying flame

(3) Shut-off hot air supply to pulverizer

(4) When pulverizer has been cooled, stop the feed supply to the pulverizer and continue operation.

(5) When the coal has stopped and the pulverizer is no longer delivering any fuel to the boiler, shut-off pulverizer.

d. Emergency Shutdown:

Paragraph 561 calls for all coal flow to the furnace to be stopped by tripping a burner shut-off valve or equivalent. The ignition system safety valves and ignitor valves in the coal feeders shall be tripped and the ignitors deenergized.

3. PROPOSED BURNER CONTROLS WITHOUT CROSS-FEED:

The existing controls were examined for compliance with the NFPA requirements and the purge circuitry was determined to be acceptable for all NFPA requirements with regard to pulverizers. The burner fire eye safety controls were found to be deficient with regard to operation per NFPA.

The most important consideration for the controls is the requirement that the pulverizer and burner system function as a unit so that starting of the pulverizer is intergrated with the light off of all the burners associated with it. If less than complete versatility is required of the existing pulverizers, a system where each pulverizer and burner is of the same number, can be designed.

To insure that only the pulverizer and feeder associated with each burner is used, it is recommended to permanently weld the coal valves in position to prevent their movement during any subsequent operation in the plant. This would provide for the utmost safety in regard to the burner management system. If this is not done there is a potential for a operator to leave the valves in the wrong location and supply fuel to a burner which is not operational.

To meet the requirements for NFPA, the following modifications will be required in the burner controls.

a. Coal ignition timer - this timer is found on line 13 and will do the same function as the existing timer, however it will be changed to an off delay from 0 to 30 minutes in contrast to the timer currently used which is 5 minutes. This will allow for the ignition to be on for a longer period of time to allow for complete burnout of the coal in the pulverizer.

b. Pulverizer control relay - a pulverizer control relay as found on line 11 of sketch C1 is added to the system to provide several functions. It will signal the pulverizer to start automatically if it has been selected by the operator, and the relay will allow the pulverizer shut-off valve to open and temperature modulation to begin. This relay receives its power through the fire eye master control relay which will automatically close the pulverizer valve in the event of loss of flame.

c. Pulverizer gate and valve circuitry - this circuitry is found on line 24 and 25 of the sketch. The function of these circuit elements is to allow the pulverizer gate to open when the pulverizer control relay is closed. It also allows a valve to be energized which will then begin to modulate the temperature in the pulverizer through the setpoint controller and indicator on the main boiler panel. These functions cease when loss of flame occurs in the burner control management system. The operator can cool down the pulverizer by resetting the temperature controller.

d. Pulverizer zero speed switch - this switch provides its function on line 28 and 29 of the sketch. When the pulverizer reaches full speed the switch closes and turns on P1 FS control relay and a light at the burner control station. The light tells the operator

that the pulverizer is at full speed. This relay provides a time lag between the start-up and the time in which coal auxilary control relay is turned on. This coal auxilary control relay controls the feeder of the pulverizer system. These contacts are found on line 9. This circuitry prevents feeding of coal before the pulverizer is capable of receiving it and delivering it to the burner. This insures that the velocity of air in the pipe is adequate to carry coal to the burner.

Lines 1 through 23 are repeated two times for both burners at each boiler. Lines 24 through 31 are repeated only once for each boiler. Line 32 and 33 is repeated twice for an individual boiler and line 34 and 35 is repeated only once for the boiler controls. Thus, each burner has a complete set of fire eye scanners, pilot starts, fuel selection valves and ignition controls. This provides safety and versitility in operation.

4. PROPOSED BURNER CONTROLS WITH CROSS-FEED:

To allow for cross-firing of pulverizer to burners, a proposed system has been sketched. This sketch is identified as sketch C2 Burner Control found at the end of this section. In addition to all of the features previously discussed this burner control system must be capable of determining which pulverizer is supplying a particular burner to allow for proper burner management. This system has three main components:

a. Cross override switch - the burner control system has integrated into it two limit switches which would be found on either the top or the bottom Y-valves of the pulverizer system. The limit switch would detect when either or both of these valves were placed in a cross delivery mode. If these limit switches were not made by the proper coal valve positon, starting the pilot would be prohibited. The operator would be alerted to the fact that these valves were not set properly by the fact that ignition would not

occur. The operator could override this logic by simultaneously pressing both pilot start and cross-override switch. This would allow for the fire eye master relay to be brought in and locked through the circuitry. This then would allow for ignition to occur. Subsequent depressing of the pilot start would not be interferred with unless there was complete loss of flame at which time both switches would have to be depressed in order to provide ignition. This arrangement provides a degree of safety to the burner management system.

b. Pulverizer select switch - To indicate to the burner controls which pulverizer is used a selector switch would be added to the controls. The selector switch has functions on line 9, 10, 11 and 12 of Sketch C-2. It essentially turns on either one of the pulverizer relays. Note that a total of four relays would be required in the system. A pair of relays in each burner and a pair of relays for each pulverizer. Nomenclature PULV 1-1 indicates burner No. 1 and pulverizer No. 1 Nomenclature PULV 1-2 indicates burner No. 1 with pulverizer No. 2 on. Subsequently there are PULV-2-1 PULV-2-2 control relays.

c. Pulverizer select circuit for gate open and modulation - Lines 24 through 27 show the relay logic necessary to turn the pulverizer valve on and modulate the temperature. These valves are set up with normally open and normally closed contacts to discourage the operator from attempting to fire both burners with the same pulverizer. The burners are set up in such a fashion, the relay logic will prevent the pulverizer valve from opening and consequently not deliver fuel to the burner providing safe operation.

As before, lines 1 through 23 will be repeated twice for each boiler and lines 24 through 31 need only done once for each boiler. Lines 32 and 33 would be repeated twice for an individual boiler and lines 34 and 35 would be required per each boiler.

5. PROPOSED PULVERIZER AND FEEDER CONTROL

At the end of this section is sketch No. C-3 and Sketch No. C-4 which lists feeder and pulverizer controls. Sketch C-3 is controls for single burner and single pulverizer operation and sketch C-4 is controls for cross-firing operation.

The feeder is controlled by the contact 1 or 2 CACR. This is a coal auxilary control relay which is found on line 9 of the sketch C-1 or C-2. Thus the feeder can only be turned on when all of the conditions have been met, principally the pulverizer is at full speed after it has been selected by the control. The additional control relay CFCR is used to compensate the pneumatic logic when both feeders are operational. At this time the pneumatic signal to the feeder must be split in half to allow for proper fuel ratio at the burners. This coal feed compensation solenoid is turned on only when both feeders are operational.

The additional control elements shown on Sketch C-4 for the feeders are the interlocks as previously discussed. These interlocks discourage the operator from operating both burners from a single pulverizer.

The pulverizers are controlled by three contacts. Induced fan auxilary control relay comes from the induced fan. This insures that air flow out of the boiler is possible when the pulverizer is on. This contact is necessary because the pulverizer will continue to stay on until the operator turns it off.

The pulverizer is turned off and on by a manual switch located at the main boiler panel. The pulverizer can not start until a signal is

received from the burner control indicating that fuel can be received by the boiler. Once the pulverizer is started it is locked in by contact from the motor starter. This allows the pulverizer to continue in operation even in a flame failure mode.

To alert the operator to a potential pulverizer failure the zero speed switch is added to the system so that whenever the pulverizer should be running, the zero speed switch must be opened by rotational speed of the pulverizer or an alarm will sound alerting the operator to this failure.

53. Normal Operation

531. The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all operating burners, maintaining normal air-fuel ratio continuously at all firing rates. This does not prohibit provisions for air lead and lag of the fuel during changes in firing rate.

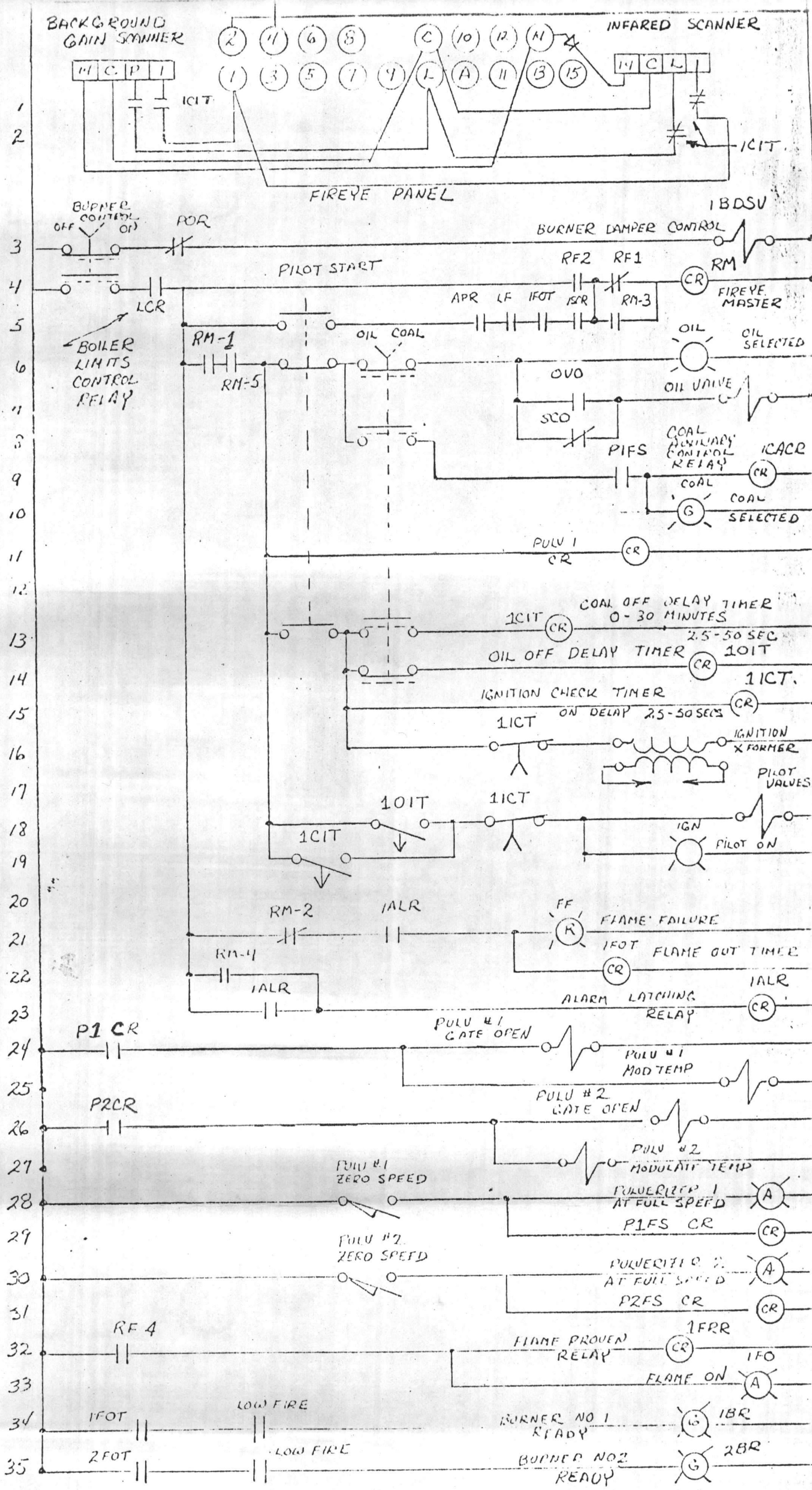
532. The firing rate shall never be regulated by varying the fuel to individual burners by means of the individual burner valves. The individual burner shutoff valves shall be wide open or completely closed (never at intermediate settings). Air registers shall be set at the firing positions as determined by tests. This does not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

533. The burner fuel and air flow shall be maintained well within the range between the maximum and minimum limits specified by the boiler manufacturer or, preferably, as determined by trial. These trials shall test for minimum load and for stable flame: (1) with all burners in service and combustion control on automatic; and (2) with different combinations of burners in service and combustion control on automatic. It must be recognized that these maximum and minimum limits with various burner combinations may change with different fuel conditions and may require retesting.

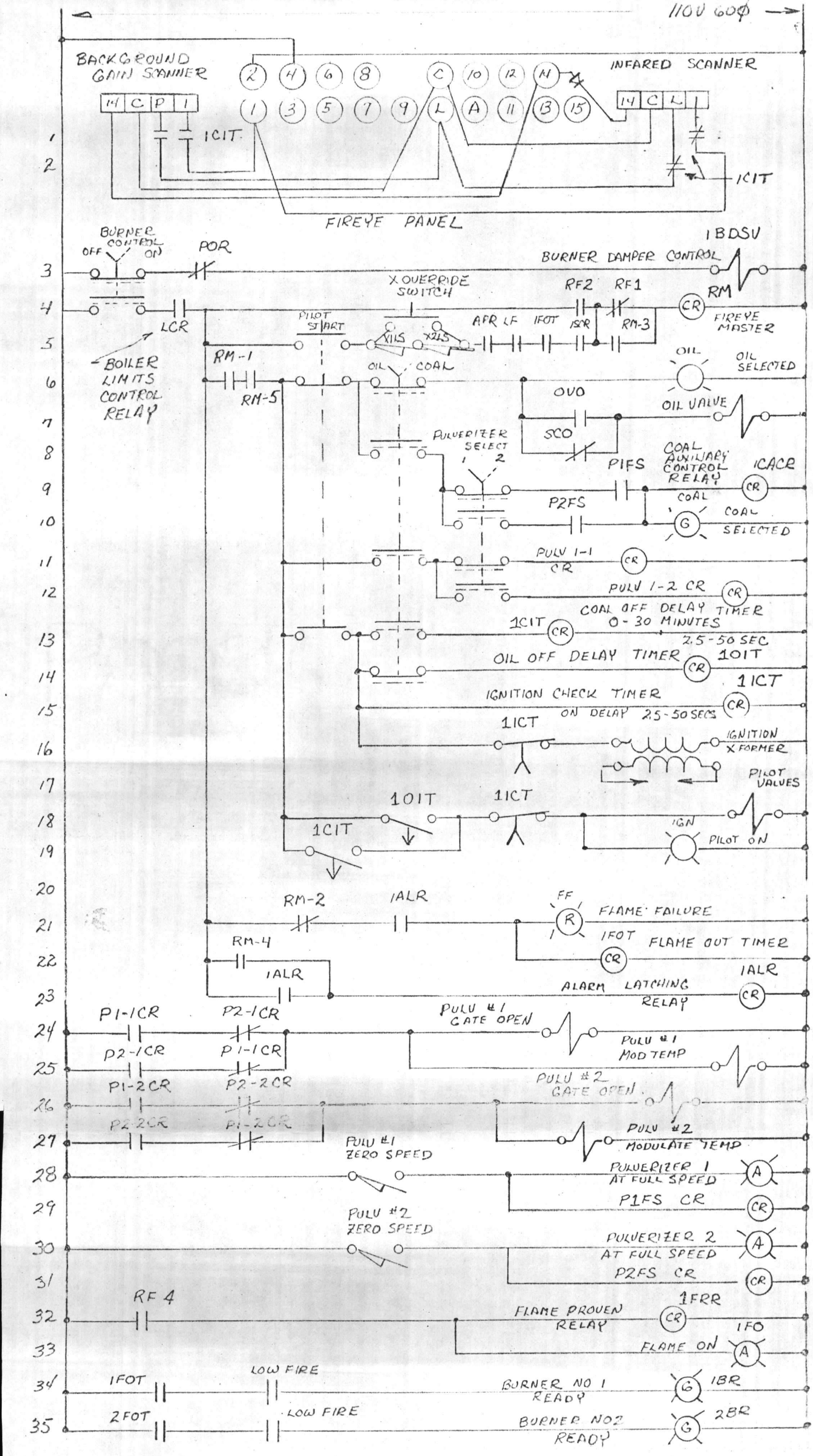
5331. If lower minimum loads are required, it is necessary to remove pulverizer(s) and burners from service and operate the remaining pulverizers at a fuel rate suitably greater than the minimum output for stable operation for the number of connected burners. The minimum fuel input permitted shall be determined by tests with various combinations of burners in service and with various amounts of excess air. This minimum fuel input may vary with the number of burners in service and shall reflect the most restrictive condition determined. These tests shall also take into consideration the transient stability factors referred to in 4123(d)(2). The ignition system shall be similarly tested.

534. Upon loss of an individual burner flame, the flow of fuel to all burners of the pulverizer subsystem shall be stopped unless provision is made to stop the flow of fuel to individual burners, in which case the fuel flow of the offending burner shall be stopped immediately. Also, the burner register(s) shall be closed if it interferes with the air-fuel ratio supplied to any other individual burner flame envelope. See 564 for list of hazards and 565 for detailed procedure for clearing pulverizers tripped while full of coal.

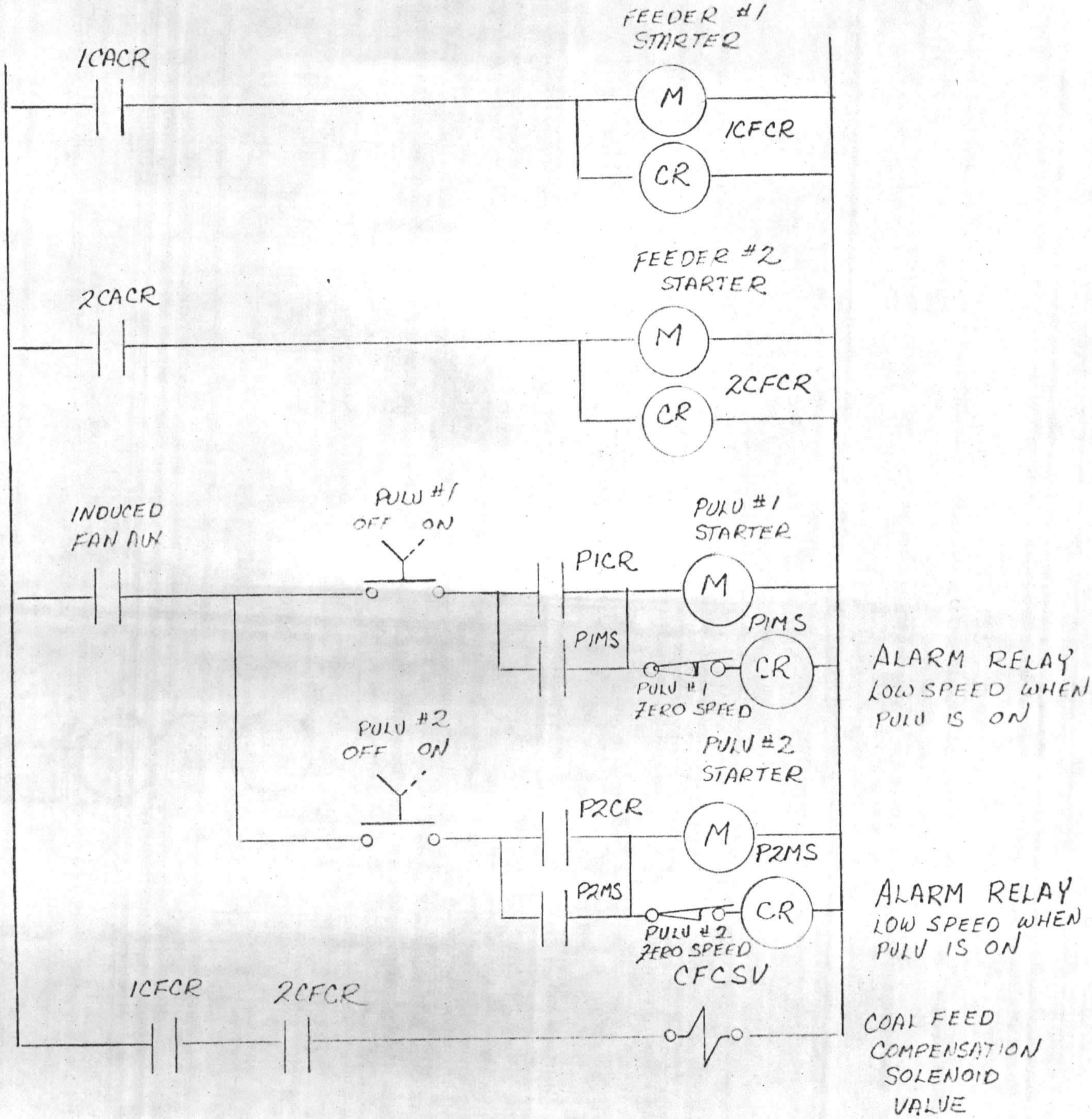
535. Total air flow shall not be reduced below 25 percent of full load volumetric air flow.



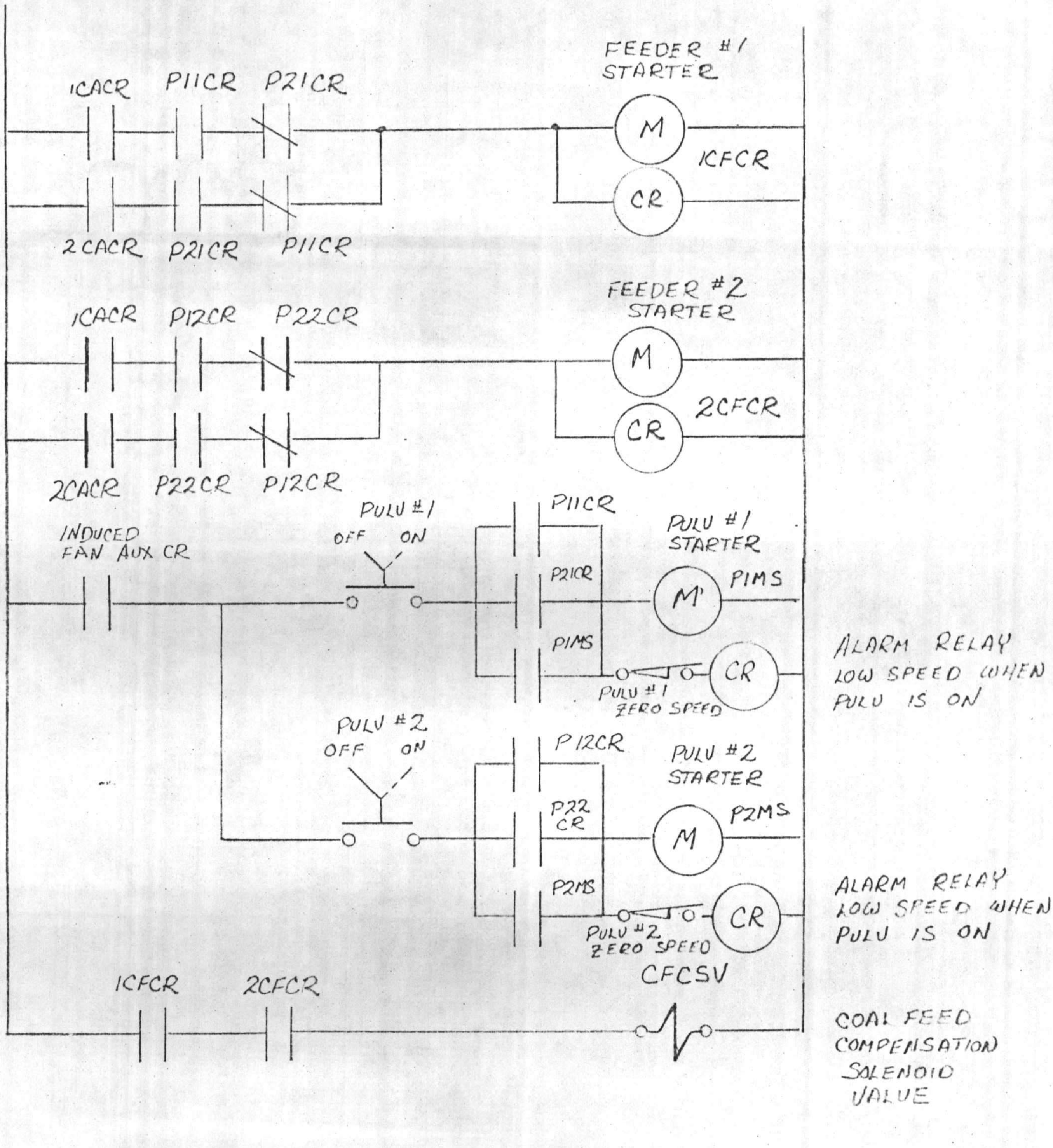
SKETCH # C1 BURNER CONTROL



SKETCH #C2 BURNER CONTROL



SKETCH C3 FEEDER & PULVERIZER CONTROL



SKETCH C4 FEEDER & PULVERIZER CONTROL

D. FUEL DELIVERY SYSTEM ANALYSIS

1. CROSS AND MULTIPLE BURNER OPERATION FROM SINGLE PULVERIZER:

The existing facility was designed initially such that a single pulverizer could feed the two burners of the boiler or supply either burner. This type of operation built-in a great deal of versatility in the operation of the facility. Currently that versatility can not be utilized because of the existing burner and safety controls will not allow it. The existing burner controls are set up to monitor a single pulverizer which has the same basic number as itself. This means that feeder No. 1 feeds pulverizer No. 1 which in turn feeds the fuel to burner No. 1. The units are all in line with the each other.

Initial design of the facility allowed for the following multiplicity of operations.

a) Feeder No. 1 Pulverizer No. 1 feeding coal to burner 1.

b) Pulverizer and feeder No. 1 feeding burner No. 2.

c) Feeder and Pulverizer No. 1 feeding both burners 1 and 2.

d) Pulverizer and Feeder No. 2 feeding burner No. 2.

e) Pulverizer and Feeder No. 2 feeding burner No. 1.

f) Pulverizer and Feeder No. 2 feeding both burners 1 and 2.

This versatility allowed for repairs to pulverizers and burners so that they could be taken off line without shutting down the boiler. With the existing burner controls this is no longer possible. It is a rule of the plant operation that only a specific pulverizer and feeder combination be used with a particular burner. This was done to simplify the electrical control interlocks from the burner controls to the feeder.

Existing boiler controls would be unsafe if, for instance, pulverizer and feeder No. 1 were to feed burner 1 and burner 2. The boiler safety controls would shut off a feeder to that particular burner, but since the other would be in a "flame made" mode the burner would not call for the feeder to be cut off. If this were to occur unburnt fuel would be allowed to enter the boiler from one of the burners. The current plant operation recognizes this safety aspect and does not allow for simultaneous burning of coal in two burners from a single pulverizer. However, the mechanical facility allows this to occur with no interlocking safety features.

The existing burner controls does not allow for cross feeding to the boiler. Burner controls No. 1 shut-off feeder No. 1 and burner controls No. 2 shut-off feeder No. 2.

The proposed burner controls as previously discussed will eliminate this hazard by forcing the operator to select the pulverizer that is supplying fuel to the burner. In the event that the wrong pulverizer is selected the burner flame management controls will shut-down the effective feeder with no safety hazard.

In order to build into this system the complete versatility of firing both burners with a single pulverizer many additional controls and mechanically operated interlock devices would have to be added. At each pulverizer is a Y-valve which directs the flow of material to one of the two pipes at the pulverizer outlet. If an automatic, versatile system were designed, these valves would be automated with a mechanical operator and interlock switches.

There is a similar valve located near the burners. This valve would likewise be required to be mechanically activated with supervisory limit switches for the made condition. Thus a total of 8 mechanically operated valves with the attendant 16 seperate limit switches would

have to be designed to provide for versatility of selecting any burner with any pulverizer. The controls located at the burner control panel would be expanded to a three-position selector switch which would call for fuel delivery from either pulverizer No. 1 or pulverizer No. 2 or pulverizer feeding both burners. The controls would recognize which switch was in operation and direct the proper closing and opening of valves to meet NFPA requirements for shut-off of coal to burner without flame. The opening and closing of these respective would be supervised by these limit switches. This would add a great deal of cost and complexity to the burner control system and therefore its use is not recommended at all for this facility.

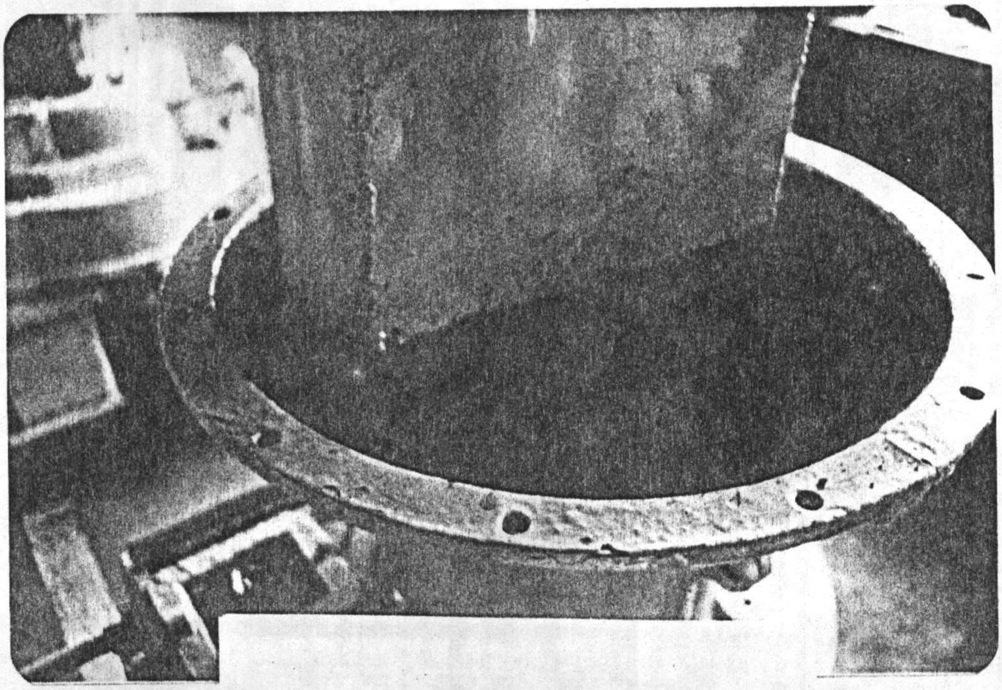
2. STEADY FEED TO PULVERIZER:

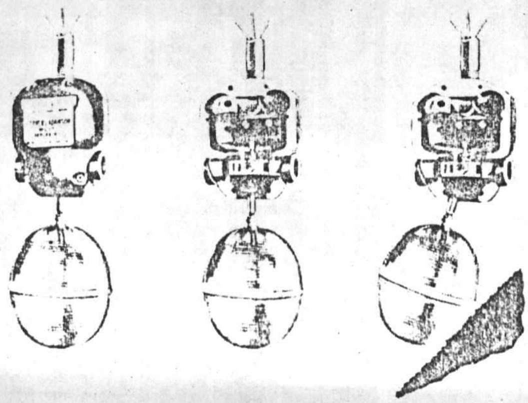
NFPA 85F Section 2-7.2 calls for an interlock for the pulverizer upon loss of fuel feed from the pulverizer. This aspect of the standards can be met by powering an alarm through the coal auxiliary control relay and a limit switch mounted on the hopper drop chute above the feeder. Such a switch would be mounted as shown in the attached sketch. This alarm would enable the operator to fire the ignitor and gain time to correct the blockage before it results in loss of flame.

3. RAW COAL SUPPLY SUBSYSTEM:

NFPA 85E Paragraph 4123 (b) (2) requests design of the coal preparation facilities to size the coal, remove foreign material and minimize interruption of coal supply to the feeders. This is accomplished at Camp LeJeune but in a very uncontrollable manner. Oversize and foreign material is presently removed by what appears to be a 4" x 4" mesh screen supported below the output of the drag flight conveyor which supplies coal to the full length bunker. It's design does not allow for removal of long, thin foreign material and stringy material such as rags. These foreign items will cause flow blockage.

A more positive design would call for a vibratory screen feeder which would be positioned at the outlet of the bucket elevator and feed material to the drag flight conveyor. A properly sized screen would reject this foreign material and allow for its collection before it could get in the bunker. This would give better assurance of uninterrupted flow of coal to the feeder.





INSTALL THIS TYPE OF COAL SWITCH TO

MONITOR COAL FLOW INTO FEEDER

COST ESTIMATE

Title: STUDY FOR BURNER CONTROL COAL FEED AND ASSOCIATED PULVERIZER

Costs Escalated to: DEC 1980

Location: CAMP LEJEUNE, N.C.

Escalation:

Prepared by: H TOUS

Date: FEB 1981

Contingency:

	$/SF	~~$/SYS~~ MATERIAL	~~SYS QUAN~~ LABOR	TOTAL	BUILDING	BUILT-IN EQUIPMENT
I RECOMMENDED WORK						
1A. SHUT OFF VALVE		73,636	7306	80942		
1B PRIMARY AIR CONTROL		50724	20540	71264		
1C FIRE PROTECTION EQUIP.		700	932	1632		
1D NEW IGNITORS		50,960	58,800	109,760		
1E. CONTROL CHANGES		744	880	1624		
TOTAL FOR 4 BOILERS		176764	88,458	265,222		
4% SALES TAX		7071				
10% PROFIT			8846			
GRAND TOTAL FOR 4 BOILERS		183835	97304	281139		
" " FOR 1 "		45959	24326	70285		
II ADDITIVES						
2A. CLEAN OUT BOX		1400	1100	2500		
2B VELOCITY TESTING		—	2400	2400		
2C SEQUENTIAL STARTING INTERLOCKS		5276	2000	7276		
2D. CROSS FEED CONTROLS		2888	2090	4978		
2E PUMP & HEATER SET		5000	1800	6800		
Sub-Total Building				$	$*	$*
2F. MISCELLANEOUS		13,800	4600	18400		*
2G. PROPANE TANK		50,300	5000	55,300		
						*
SUBTOTAL OF ADDITIVES		78,664	18990	97654		
4% SALES TAX		3147				
10% PROFIT			1899			
TOTAL OF ADDITIVES		81811	20889	102,700		*
						*
						*
Sub-Total Supporting Facilities				* $		

Total Estimated Contract Cost: 1 Jan	$
Contingency ____%	$
SIOH 5.5%	$
Total Budget Cost	$
Rounded	$

*Asteric indicates these totals on 1391.

MATERIAL & LABOR COST ESTIMATE 5ND LANTDIV 4-11012/5 (REV. 10/74)

PREPARED BY H/P T.W

ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND

Const. Contr. No.

FUNDS AVAIL.

NORFOLK, VIRGINIA

DATE 2/20/81

PROJECT PULVERIZER STUDY

LOCATION CAMP LEJEUNE N.C.

☐ PRELIM. ☒ FINAL

ITEMS	QUANTITY	UNIT	MATERIAL COST UNIT	MATERIAL COST TOTAL	LABOR COST UNIT	LABOR COST TOTAL	TOTAL COST	REMARKS
1A. SHUT OFF VALVE								
AIR TIGHT, HIGHTEMP AUTOMATIC VALVE	8	EA	8807	70456	240	1920	72376	Stock Eqm't Co
MODIFY DUCTWORK FOR VALVE	8	|	75	600	160	1280	1880	404-452-0952
TEST PULVERIZER FOR LEAKAGE	8	|	25	200	60	480	680	
MODIFY PULVERIZER OBSER PORTS	8		40	320	60	480	800	
MODIFY PULVERIZER CLEAN OUT DOORS	16		50	800	60	960	1760	
SEAL PULVERIZER FLANGE	8	V	100	800	200	1600	2400	
CONSTRUCT SCAFFOLDING & RENTAL	80	CCF	3.25	260	4.32	346	606	"Means" Estimate Gu[illegible]
REINFORCE PULVERIZER DUCTING	8	EA	25	200	30	240	440	
TOTAL				73,636		7306	80942	
1B. PRIMARY AIR CONTROL								
MODIFY & REMOVE EXISTING DUCTWORK	4	EA	25	100	120	480	580	H/P
NEW DUCT WORK STEEL	4800	LBS	.51	2448	1.30	6240	8688	"Means"
MODIFY DUCTWORK FOR DAMPERS	8	EA	10	80	60	480	560	H/P
DAMPER ASSEMBLY	8		100	800	15	120	920	"Means"
INSULATE DUCTWORK, DAMPERS, ETC	480	SF	2.50	1200	4.40	2112	3312	"
ADD SCREENING TO EXIST DUCT	4	EA	24	96	17	68	164	"
TEMPERATURE SENSOR	8		250	2000	80	640	2640	Bailey Controls
TRANSMITTER - TEMP	8		400	3200	60	480	3680	404-934-0212
SET POINT CONTROLLER	8		1100	8800	120	960	9760	"
I/P DAMPER CONTROL W/CYL, LINKAGE, SWTCHS	16		1200	19200	75	1200	20400	"
PRESSURE SENSOR - ELECTRONIC	8		200	1600	40	320	1920	"

MATERIAL & LABOR COST ESTIMATE 5ND LANTDIV 4-11012/5 (REV. 10/74)

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PROJECT PULVERIZER STUDY

LOCATION CAMP LEJEUNE N.C.

☐ PRELIM. ☒ FINAL

ITEMS	QUANTITY	UNIT	MATERIAL COST		LABOR COST		TOTAL COST	REMARKS
			UNIT	TOTAL	UNIT	TOTAL		
FEED FORWARD CONTROLLER	8	EA	1400	11200	80	640	11840	Bailey Controls
ENGR CHECK OUT, TEST, CALIBRATE	8	"		—	850	6800	6800	"
TOTAL				50724		20540	71264	
1C. FIRE PROTECTION EQUIPMENT								
1" SCH 40 BLACK PIPE - STEAM LINE	200	LF	1.18	236	2.38	476	712	
1" INSULATION ON PIPE	200	"	.90	180	1.00	200	380	
1" MANUAL STEAM VALVE	8	EA	28	224	7	56	280	
MISCELLANEOUS FITTINGS	LS			60		200	260	
TOTAL				700		932	1632	
1D. LARGER CAPACITY IGNITOR								
IGNITOR AND ASSOCIATED CONTROLS	8	EA	5000	40,000	300	2400	42400	AFSCO (CEA Combustion) 404-987-0660
NEW PIPE SUPPORT IN BURNER	8	"	100	800	600	4800	5600	
ELECTRICAL WIRING - POWER	8		200	1600	900	7200	8800	Boiler Eqmt Services
- CONTROLS	8		400	3200	1500	12000	15200	404-452-8811
PURGE AND ATOMIZING PIPING	8		200	1600	750	6000	7600	
ATOMIZING REGULATING VALVE	4		400	1600	600	2400	4000	
OIL PIPING AND FITTINGS	8		120	960	900	7200	8160	
CONTROL BOX MOUNTING	8		100	800	300	2400	3200	
START UP & TESTING	8	"	50	400	1800	14,400	14800	
TOTAL				50,960		58,800	109760	

MATERIAL & LABOR COST ESTIMATE 5ND LANTDIV 4-11012/5 (REV. 10/74)

SHEET 3 of 3

PREPARED BY H/P TW.

ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND

Const. Contr. No.

FUNDS AVAIL.

NORFOLK, VIRGINIA

DATE 2/20/81

PROJECT PULVERIZER STUDY

LOCATION CAMP LE JEUNE

☐ PRELIM. ☒ FINAL

ITEMS	QUANTITY	UNIT	MATERIAL COST UNIT	MATERIAL COST TOTAL	LABOR COST UNIT	LABOR COST TOTAL	TOTAL COST	REMARKS
1E. CONTROL CHGS w/o CROSSFEED								
COAL IGNITION TIMER 0-30 MIN	8	EA	60	480	30	240	720	
CONTROL RELAYS PULV 1-2 CR	8	EA	20	160	15	120	280	
TERMINATIONS "NEW WIRE	104	EA	1	104	5	520	624	
TOTAL				744		880	1624	
2A. CLEAN OUT BOX PULVERIZER								
CONSTRUCT REMOVABLE BOX	10	EA	100	1000	50	500	1500	
MODIFY PULVERIZER TO ACCEPT BOX	8	EA	50	400	75	600	1000	
TOTAL				1400		1100	2500	
2B. TESTING OF AIR VELOCITY								
PERFORM TEST WORK	LS						2400	Air-Techniics 404-429-9292

MATERIAL & LABOR COST ESTIMATE 5ND LANTDIV 4-11012/5 (REV. 10/74) SHEET 4 of 5

PREPARED BY H/P TW

ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND

NORFOLK, VIRGINIA

Const. Contr. No.

FUNDS AVAIL.

DATE 2/20/81

PROJECT PULVERIZER STUDY LOCATION CAMP LESEUNE N.C ☐ PRELIM. ☒ FINAL

ITEMS	QUANTITY	UNIT	MATERIAL COST UNIT	MATERIAL COST TOTAL	LABOR COST UNIT	LABOR COST TOTAL	TOTAL COST	REMARKS
2C SEQUENTIAL STARTING INTERLOCKS								
INSTALL ZERO SPEED SWITCH	8	EA	500	4000	100	800	4800	
CONTROL RELAYS P1FS, P2FS	8		25	200	15	120	320	
ANNUNCIATOR RELAY	8		25	200	15	120	320	
ALARM ANNUNCIATOR	8		45	360	15	120	480	
DISPLAY LIGHTS	8		30	240	15	120	360	
TERMINATIONS - NEW WIRE	96		1	96	5	480	576	
CONDUIT RUN TO PULV STARTER	LS			180		240	420	
Total				5276		2000	7276	
2D. CROSS FEED CONTROLS								
X OVERIDE PUSH BUTTON	8	EA	20	160	15	120	280	
X LS LIMIT SWITCH	8		120	960	70	560	1520	
OIL-COAL SWITCH	8		63	504	15	120	624	
PULVERIZER SELECTOR SWITCH	8		63	504	15	120	624	
PULV RELAYS - ADD TO 1E & 2C	16		30	480	15	120	600	
TERMINATIONS "	160		1	160	5	800	960	
CONDUIT RUN	LS			120		250	370	
TOTAL				2888		2090	4978	

MATERIAL & LABOR COST ESTIMATE 5ND LANTDIV 4-11012/5 (REV. 10/74)

SHEET 5 of [illegible]

PREPARED BY H/P TW

ATLANTIC DIVISION NAVAL FACILITIES ENGINEERING COMMAND

Const. Contr. No.

FUNDS AVAIL.

NORFOLK, VIRGINIA

DATE 2/20/81

PROJECT PULVERIZER STUDY

LOCATION CAMP LEJEUNE N.C.

☐ PRELIM. ☒ FINAL

ITEMS	QUANTITY	UNIT	MATERIAL COST		LABOR COST		TOTAL COST	REMARKS
			UNIT	TOTAL	UNIT	TOTAL		
2E. ADDITIONAL PUMP & HEATER SET								
PUMP & HEATER SET	1			5000		1800	6800	APSCO 404-987-0660
2F MISCELLANEOUS								
RAW COAL SCREEN	1	EA		12300		600	12900	Xondra
CHUTE	LS			500		400	900	404-633-6872
BIN	LS			1000		400	1400	
NEW COMBUSTION CONTROLS DRAWING FOR EXISTING S/S.		LS				3200	3200	
TOTAL				13,800		4600	18,400	
2G. PROPANE VAPORIZER & TANK								APPLIED ENGINEERING
								404-934-0420
VAPORIZER		LS		15,800		500	16,300	
30,000 GALLON TANK		LS		30,000		200	30,200	
VALVES AND TRIM		LS		2200		900	3,100	
MANWAY & MULTIPORT RELIEF & STACK		LS		2000		100	2100	
TRANSPORTATION		LS				2600	2600	
BASE FOR TANK		LS		300		700	1000	
TOTAL				50300		5000	55,300	

APPENDIX A & B

APPENDIX A EXCERPTS FROM NFPA 85F - 1978

1-2.2 This *Standard for the Installation and Operation of Pulverized Fuel Systems* (NFPA 85F-1978) is applicable to new installations and to major alterations or extensions of existing equipment for the preparation and burning of fuel in pulverized form contracted for subsequent to June 1, 1978. The standard is not retroactive.

1-2.3 Since this standard is based upon the present state of the art, its application to existing installations is not mandatory. Nevertheless, operating companies are encouraged to adopt those features of this standard which are considered applicable and reasonable for existing installations.

1-3.1.2 The principal requirement of pulverized fuel systems and their components is that they be capable of long-term continuous and proper operation. It is essential that unwanted interruptions be kept to an absolute minimum because of the general combustible and explosive nature of the pulverized fuels. Experience shows that fires and/or explosions are most likely to occur during start-up or shutdown or after an emergency shutdown.

Pulverized fuel systems must incorporate all necessary equipment and controls to provide for repeated safe cycles of start-up, operation, and shutdown, whether these cycles are of long or short duration.

1-3.4.2 It is of fundamental importance to evaluate and make provisions for adequate integration of manual and automatic safety features. The maximum number of automatic trip features does not necessarily provide for maximum overall safety. Some trip functions result in additional operations which increase exposure to hazards. It is important to weigh the benefits against any disadvantage of various trip functions.

1-3.6.1 For safe operation, proper coordination of the overall design and functional objectives are important. It cannot be assumed that correctly designed equipment and the manufacturer's operating instructions may be wholly relied upon to ensure a safe operating system without the benefit of a competent technical, operating, and maintenance plant organization.

1-3.6.3 The quality of maintenance of control equipment, including interlocks and alarms, must be sufficiently high to maintain the system in a safe and reliable operating condition. All equipment should, with reasonable operation and maintenance, operate over an acceptable period of time without being taken out of service.

2-2.2 The system shall include indicators and annunciators which will provide the operator with adequate information about significant operating conditions, both normal and abnormal, throughout the system.

2-3.3 Positive means shall be provided to assure that all pipe velocities are equal to or above the minimum velocity required for fuel transport. Testing during initial start-up shall be performed to verify that individual pipe velocities are adequate.

2-4.1 Where inerting is specified, it shall be permanently installed and equipped with suitable connections which shall be a minimum of one inch diameter. Injection shall be controlled by readily operable valves or dampers.

2-5.1 Direct-Fired Systems.

NOTE: This system may have the fan located either following or ahead of the pulverizer. If auxiliary (by-pass) air is used, a damper is required in this line. The usual direct-firing pulverized fuel system is comprised of the following components (see *Figure 2-5.1*):

(a) Raw fuel bunker.
(b) Raw fuel gate.
(c) Raw fuel feeder.
(d) Flow control of raw fuel.
(e) Discharge hopper.
(f) Air (or flue gas) swept pulverizer.
(g) Pulverizer air fan or exhauster.
(h) Source of hot air (or flue gas).
(i) Source of cold air (or flue gas).
(j) Temperature control of air (or flue gas).
(k) Flow control of air (or flue gas).
(l) Piping and ducts.
(m) Valves.
(n) Dampers.
(o) Burners.
(p) Means of inerting.
(q) Safety interlocks and alarms.

2-6.7.1 Pulverizers and pulverized fuel collecting systems shall be equipped with suitable connections for fire extinguishing. These connections shall be at least one inch (25mm) diameter and shall be adequate to pass the amount of extinguishing material required.

2-7.2 Interlocks for pulverizers of direct-fired systems shall be arranged to trip in the following sequence:

(a) Loss of primary air flow trips raw fuel feeder of affected pulverizers.

NOTE: Manufacturer's instructions regarding closing of burner line valves, dampers, and tripping of pulverizer should be followed.

(b) Failure of pulverizer trips raw fuel feeder.

(c) Closure of all pulverizer discharge valves trips raw fuel feeder.

(d) Loss of fuel feed through the pulverizer energizes alarms, and blocks restarting of fuel feed until feeder start-up conditions are re-established.

NOTE: Several means are available to indicate loss of fuel feed through the pulverizer, loss of fuel feed to the pulverizer, loss of fuel stored within the pulverizer, and loss of fuel input to the burners. At least one, but preferably a combination of means, should be reliably established and used to actuate loss of fuel interlocks.

2-7.3 Permissive sequential starting interlocks shall be arranged so that after appropriate furnace interlocks have been satisfied in accordance with NFPA 85E-1978, *Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*, the pulverizer can be started only in the following sequence:

(a) Ignitors for all of the burners served by the pulverizer in service and proven.

(b) Start primary air fan or exhauster.

(c) Establish minimum air flow.

(d) Start pulverizer.

(e) Start raw fuel feeder.

3-2.4.1 Fire in any part of a pulverized fuel system shall be considered serious and dealt with promptly. Inerting and extinguishing media shall be selected from the following:

(a) Water.

(b) Carbon dioxide.

(c) Inert vapor (such as steam).

(d) Nitrogen.

(e) Other inert gases.

3-2.4.2 The following procedures for fighting fires shall be considered with appropriate modification for specific systems, specific locations of fire, or as influenced by the manufacturer's requirements:

(a) A fire detected in an operating low-storage pulverizer may generally be extinguished by shutting off the hot air, increasing the raw fuel feed as much as possible, and continuing to operate with cold air. If the temperature at the pulverizer outlet does not drop within a few minutes, introduce water into the raw fuel and/or cold air streams. However, the water must be added in such quantities and at such locations as not to cause hang-up or interruption of the raw fuel feed nor to stir up any deposits of combustible material. When all evidence of fire has disappeared, shut off the water and the raw fuel feed, allow the pulverizer to run with cold air passing through it for at least 5 minutes to purge the system, and minimize any accumulation of water.

(b) Stop the pulverizer, isolate the system and inert. Avoid disturbing any accumulation of dust within the pulverizing equipment. Do not open any access doors to the pulverizer until the fire is extinguished and all temperatures have returned to ambient. After isolation of the pulverizer is verified, follow procedures outlined in 3-2.4.6.

(c) Shut off the feeder and allow the pulverizer to clear itself of fuel. Maintain a flow of cold air through the pulverizer until all evidence of fire has disappeared. When the pulverizer is cold, shut it down. Isolate the pulverizer and follow procedures outlined in 3-2.3.

(d) Because of the relatively large amount of fuel in the high-storage pulverizer, the procedure in 3-2.4.2 (a) may not be successful. In this event, stop the raw fuel feed and the pulverizer immediately. Stop fans, isolate the system and inert.

3-3.1 Starting Sequence.

3-3.1.1 The starting sequence shall be as follows:

(a) Start up all necessary combustion system equipment such as fans, ignitors, etc., required in proper sequence.

(b) Open cold or tempering air damper.

(c) Start primary air fan or exhauster, if driven separately from the pulverizer.

(d) Open primary air flow control damper to a predetermined setting which is at least sufficient to provide minimum burner line velocity.

(e) Open burner line valves, if any, on the pulverizer to be started.

(f) Start pulverizer.

(g) Start raw fuel feeder.

(h) Place pulverizer outlet temperature control, primary air flow control, and raw fuel feed control on automatic.

3-3.2 Normal Operation.

3-3.2.1 The pulverizer output shall be regulated by increasing or decreasing its fuel and air supplies in accordance with the manufacturer's procedures or as determined by field tests.

3-3.2.2 The individual burner shutoff valves, if provided, shall be wide open or completely closed (never at intermediate settings).

3-3.2.3 For operation at reduced pulverizer loads, the auxiliary air dampers, where provided, shall be used to maintain minimum burner line velocities.

3-3.2.4 A pulverizer shall not be operated below its minimum air and/or fuel stop setting.

3-3.3 Normal Shutdown.

3-3.3.1 The shutdown sequence shall be as follows:

(a) Establish required combustion system conditions for shutdown.

(b) Shut off the hot air and open up the cold air to cool down the pulverizer.

(c) When the pulverizer is cooled, stop the feeder and continue operation of the pulverizer with sufficient air flow to remove all fuel from the pulverizer and associated burner lines. Continue cooling if required.

(d) Shut the pulverizer down when the pulverizer system is empty.

(e) Close all individual burner line shutoff valves, if provided, unless otherwise directed by manufacturer's instructions.

NOTE: When a high storage pulverizer is shut down with a significant amount of coal remaining in the pulverizer, this coal is subject to spontaneous combustion if it is not kept below its ignition temperature. In order to minimize explosions in the pulverizer or burner lines, the safest procedure is to cool down and empty the pulverizer, the same as for a low storage system. When this procedure is not followed, it is recommended that the pulverizer be blanketed with an inert gas. A less desirable procedure is to rotate the pulverizers at specified intervals in order to mix the charge of balls and coal and prevent the spontaneous generation of heat sufficient to ignite the coal. The danger in this latter procedure is that if it is not done often enough and the coal is already ignited, the rotation of the pulverizer may trigger an explosion. Consult the manufacturer for specific instructions.

3-3.4 Clearing Procedures.

3-3.4.1 For pulverizers that are tripped while containing a charge of fuel, the following procedure shall be used to clear fuel from the pulverizer as soon as possible after it has been tripped:

(a) Isolate all shutdown or tripped pulverizers.

(b) Start up one pulverizer in accordance with the principles and sequences listed in 3-3.1.

NOTE: These procedures will also sweep the transport lines clean.

(c) Continue to operate the pulverizer until empty and in normal condition for shutdown. When the operating pulverizer is empty of fuel, proceed to another pulverizer and repeat the procedure until all are cleared of fuel.

APPENDIX B EXCERPTS FROM NFPA 85E - 1978

13. Because this standard is based upon the present state of the art, application to existing installations is not mandatory. Nevertheless, operating companies are encouraged to adopt those features of this standard which are considered applicable and reasonable for existing installations.

14. Emphasis is placed upon the importance of combustion control equipment, safety interlocks, alarms, trips and other related controls which are essential to safe boiler operation.

213. Numerous situations can arise in connection with the operation of a boiler-furnace which will produce explosive conditions. Although special hazards are covered in detail in paragraph 262, the most common experiences are:

2131. An interruption of the fuel or air supply or ignition energy to the burners, sufficient to result in momentary loss of flames, followed by restoration and delayed re-ignition of an accumulation.

2132. The accumulation of an explosive mixture of fuel and air as a result of loss of flame at one or more burners in the presence of other burners operating normally or during lighting of additional burners.

2133. The accumulation of an explosive mixture of fuel and air as a result of a complete furnace flameout and the ignition of the accumulation by a spark or other ignition source, such as attempting to light burner(s).

2134. Fuel leakage into an idle furnace.

222. It is of fundamental importance to evaluate and make adequate provisions for optimum integration of manual and automatic safety features. The maximum number of automatic trip features does not necessarily provide for maximum over-all safety. Some trip actions result in additional operations which increase exposure to hazards. It is important to weigh the benefits against any disadvantages of various trip functions.

2523. Another basic objective is the application of the open register light-off and purge rate procedure. This procedure maintains volumetric air flow at or above purge rate during all operation of the boiler. The term "Open Register Light-Off" was initially adopted to distinguish the procedure from the old practice of lighting off with closed registers, that is, with all burner air registers closed except for the burner to be lit. This outmoded closed register practice made it difficult to control the air through the burner to be lit and thereby increased the risk of a flameout even with very rigid rules of procedure.

The open register-purge rate procedure is based upon the concept that the following three basic operating conditions will significantly improve the margin of operating safety, particularly during start-up.

(1) Minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction.

(2) Means for establishing the desired fuel-rich condition at individual burners during light-off.

(3) An air-rich furnace atmosphere during the light-off and warm-up by maintaining total furnace air flow at the same rate as that required for the furnace purge.

In its simplest form the basic procedure which satisfies these three operating objectives is as follows:

(a) All or most of the burner air registers are placed in a predetermined open position.

(b) The furnace and boiler setting are purged with the burner air registers in the position specified in item (a). The total air flow for purge must not be less than 25% of full load volumetric air flow.

(c) Light the first burner or group of burners without any change in air flow setting or in burner air register position.

Each boiler shall be tested to determine whether any modifications are required in order to obtain satisfactory ignition, or to satisfy other design limitations during light-off and warm-up. For example, some boilers will be purged with the registers in the normal operating position. In this event it may be necessary to momentarily close the registers of the burner being lighted to establish ignition. However, unnecessary modifications in the basic procedure shall be avoided, thereby satisfying to the greatest degree possible the three basic objectives set forth above, particularly that of keeping the number of equipment manipulations to a minimum.

2621. Common hazards are involved in the combustion of solid, gaseous and liquid fuels. In addition, each of these fuels has special hazards related to its physical and chemical characteristics.

Characteristics of coal and coal firing which require special consideration are:

(g) The burning of pulverized coal requires close integration of the pulverizer system. In the system in most common use the pulverizer and the burner systems function as a unit so that starting of the pulverizer is integrated with the light-off of all burners associated with it. Precautions must be taken to prevent pre-ignition of the pulverized coal in the burner pipe. This is accomplished principally by preventing the velocity of the transport air from falling below a predetermined value during operation and by purging the pipes with at least this air flow during the shut down procedure. Also by operating above these minimum velocities, settling out or drifting of the fuel in the burner pipe is prevented. The danger associated with this drifting is that the accumulated coal may cause a furnace explosion as the flow in that pipe is increased. A means is also required to prevent reverse flow of furnace gases into idle burners or pulverizers.

(h) The difficulty in equalizing transport air velocities in multiple coal/air pipes from the same pulverizer introduces an additional need to maintain minimum transport air velocity, as described in paragraph (g) above. Positive means must be provided for controlling individual pipe velocity, or the minimum safe pipe velocity must be based on the lowest velocity pipe associated with a particular pulverizer. This may require testing during initial start-up of the boiler.

(i) It is necessary to dry the coal to prevent pulverizer choking or impaired combustion. This is usually accomplished by supplying hot air to the pulverizer. Temperature control is normally maintained by mixing cold tempering air with the hot air from the air heater. The coal-air temperature leaving the pulverizer must be maintained within limits. Too low an outlet temperature impedes pulverization. Too high an outlet temperature causes coking or burning of burner parts, and increases the possibility of pulverizer fires. The pulverizer outlet temperature is adjusted for the type of coal being burned. Maintaining a controlled outlet temperature also aids in controlling the relationship between fuel and primary air or gas.

(j) With a low storage pulverizer, provisions must be made for cooling down and emptying the pulverizer as part of the process of shutting down the burners associated with it. If the pulverizer is tripped under load, follow the clearing procedure outlined in Section 565 to prevent spontaneous combustion and a possible explosion in the pulverizer or burner lines.

Classification of Igniter — Igniters are designated by use as class 1, class 2, or class 3 as defined below in this section and as verified by test (See 4123(d) (3)). It is dangerous to use class 3 igniters with pulverized coal main fuel. It is strongly recommended that only class 1 or class 2 igniters be applied to coal burners, and after existing boilers are found to have class 3 igniters, they should be up-graded to at least class 2. Many factors affect the classification of the igniters among which are: the characteristics of the main fuel; the furnace and the burner design; and the igniter capacity and location relative to the main fuel burner.

Class 1 (Continuous Igniter)

An igniter applied to ignite the fuel input through the burner and to support ignition under any burner light-off or operating conditions. Its location and capacity are such that it will provide sufficient ignition energy, generally in excess of 10% of full load burner input, at its associated burner to raise any credible combination of burner inputs of both fuel and air above the minimum ignition temperature.

Class 2 (Intermittent Igniter)

An igniter applied to ignite the fuel input through the burner under prescribed light-off conditions. It is also used to support ignition under low load or certain adverse operating conditions. The range of capacity of such igniters is generally 4% to 10% of full load burner fuel input. It shall not be used to ignite main fuel under uncontrolled or abnormal conditions. The burner shall be operated under controlled conditions to limit the potential for abnormal operation, as well as to limit the charge of fuel to the furnace in the event that ignition does not occur during light-off. Class 2 igniters may be operated as class 3 igniters.

Class 3 (Interrupted Igniter)

A small igniter applied particularly to gas and oil burners to ignite the fuel input to the burner under prescribed light-off conditions. The capacity of such igniters generally does not exceed 4% of the full load burner fuel input. As a part of the burner light-off procedure the igniter is turned off before the timed trial for ignition of the main burner has expired. This is to insure that the main flame is self-supporting, is stable and is not dependent upon ignition support from the igniter. The use of such igniters to support ignition or to extend the burner control range shall be prohibited. This class of igniter is dangerous for light-off or sustaining ignition of main coal burners.

(b) Raw Coal Supply Subsystem

(2) The raw coal unloading, storage, transfer and preparation facilities shall be designed and arranged to properly size the coal, to remove foreign material, and to minimize interruption of the coal supply to the coal feeders. This includes the installation of breakers, cleaning screens and magnetic separators where necessary. Detection and corrective means shall be provided to insure adequate coal flow to the feeder. One of the greatest hazards in the operation of pulverized coal-fired boilers is partial or total stoppage of the raw coal supply to the coal feeder. The resulting interruption causes transients, significant reduction or cessation of the pulverized coal supply to the burners with the accompanying hazard of loss of ignition and reignition of an accumulation.

(c) Pulverizer Subsystem

(1) Coal pulverizing equipment shall be designed to provide a range of capacity which will minimize starting and stopping of pulverizers during boiler load changes. It shall produce satisfactory coal fineness over a specified range of coal analyses and characteristics. Pulverizer systems shall be designed in accordance with NFPA 85F-1978 "Pulverized Fuel Systems." The pulverizer system shall be designed to minimize the possibility of fires starting in the system and means shall be provided to extinguish fires.

(4) Means shall be provided to control pulverizer outlet temperature within limits suitable for the coal being fired.

(e) Ignition Subsystem

(1) The ignition subsystem shall be properly sized and arranged to smoothly ignite the main burner input within the limitation of the igniter classification. It shall be tested to verify that the igniters furnished meet the requirements of the class specified in the design.

422. System Requirements

(a) Furnace input shall be maintained in accordance with a suitable energy demand under all credible conditions.

(b) The air/fuel mixture shall be maintained within safe limits as established by test under any boiler output conditions within the controllable operating range of the subsystem.

(c) For start-up conditions means shall be provided to maintain a constant volumetric total air flow (not less than 25%) while

fuel is controlled to satisfy start-up rates and within the established limits to be compatible with air flow at each burner. Means shall also be provided and suitable operating procedures shall be established to preclude the possibility of an unsafe fuel/air ratio condition at each burner.

(d) Provide means for setting minimum and maximum limits on the fuel and air control systems to prevent these systems from providing fuel and air flows beyond the stable flame limits of the fuel burning system. These minimum and maximum limits shall be defined by the burner manufacturer and verified by operating tests. [See Section 4123 (d) (2).]

(e) Means shall be provided to control the pulverizer coal-air temperature within the required limits.

(f) Means shall be provided to assure adequate primary air for transport of the required fuel input.

(g) When changing the rate of furnace input, the air flow and fuel flow shall be changed simultaneously at the proper rates to maintain safe air/fuel ratio during and after the changes. This does not prohibit provisions for air lead and lag of fuel during changes in firing rate. The practice of placing either fuel or air flow control on automatic without the other also being on automatic shall be discouraged.

(h) On balanced draft furnaces, maintain furnace draft at the desired set point in the combustion chamber.

(i) Means shall be provided to prevent the control system from demanding a fuel-rich mixture. Control action toward more fuel and less air shall be blocked when air/fuel ratio decreases below preset value.

(j) Means shall be provided to cut back fuel to available air. If the air/fuel ratio should decrease below an appropriate preset value, control actions toward less fuel and/or more air shall be taken.

(k) It is recommended that oxygen and combustible meters be provided as an operating guide.

(l) Coal flow devices on each pulverizer are recommended as a part of the combustion control and burner control systems to provide indices of total fuel vs. total air flow. These devices are also a valuable operating guide.

(m) Provide means to permit as much on-line maintenance of combustion control equipment as possible.

(n) Provide a means for calibration and check testing of combustion control and associated safeguard equipment.

522. Starting Sequence

(a) Start induced-draft fan(s) if provided.

(b) Start forced-draft fan(s).

(c) If regenerative type air heaters and gas recirculation fans are furnished, start them in the manner recommended by the boiler manufacturer.

(d) In line with the objectives set forth in Section 51, it is preferable to purge the boiler with all of the burner registers open to the light-off position. [See Para. 2523 (a).] In any event, open dampers and burner registers to the position necessary to insure a complete purge of the furnace, boiler passes and ducts. If tests show that the required air flow and air distribution to the initial operating burners for positive ignition and stable flame cannot be maintained when the registers are open, then one or more idle burner registers may be closed.

(e) Adjust air flow rate to purge air flow, and purge the setting with not less than five changes in volume but, in any event, for a continuous period of not less than five minutes. Purge air flow shall be equal to or greater than 25 percent of full load volumetric air flow (see precautions 587) for a period of five minutes, which experience has shown to be adequate flow for a satisfactory purge, unless tests on a specific unit demonstrate satisfactory purging with different values of flow and time.

(f) See Section 6 (Interlock Systems) for permissive conditions in "Purge System" that must be satisfied.

(g) If gas recirculation fans are furnished, they can either be taken out of service or left in service as required by the boiler manufacturer for start-up conditions.

(h) Regenerative air heaters shall be continued in service during the start-up period with pulverized coal. A number of benefits occur: examples are:

(1) Heated air may be supplied to the pulverizer to aid in drying the coal during pulverizing.

(2) Heated air may be supplied to the feeders to aid in keeping the coal flowing at low firing rates.

(3) Heated combustion air aids in burning the fuel more completely during warm-up and low loads.

(i) Open the ignition fuel supply valve (E) and check that the igniter fuel control valve (F) is holding the recommended fuel pressure for proper igniter capacity.

(j) Start the igniters for all burners served by the pulverizer to be placed in service. If one or more of the igniters fail to light within ten seconds, shut the igniter shutoff valve, determine and correct the cause of the failure to light. Because air flow is at purge rate, repurge is not necessary before retrying the igniters. Repeated retrials of igniters within a short time interval is prohibited.

(k) With the coal feeder off, open all gates between the coal bunker and pulverizer feeder and make sure coal is available to the feeder.

(l) After making sure that the igniters are established and are providing appropriate ignition energy for the main burners, start the pulverizing equipment following the equipment manufacturer's instruction. If necessary readjust furnace air flow after conditions stabilize, but air flow shall not be reduced below the purge rate.

(m) Start the feeder at a predetermined setting. With the feeder delivering coal to pulverizer, pulverized coal will be delivered to the burners after the specific time delay required to build up storage in the pulverizer and transport the fuel to the burner. This time delay which is determined by test, may be a few seconds with some types of equipment or as much as several minutes with others.

(n) The main burner fuel admitted to the furnace should ignite immediately. Satisfactory ignition should be obtained within ten seconds following the specific time delay described in (m).

The master fuel trip shall be initiated on failure to ignite or loss of ignition on burners served by the first pulverizer placed in operation unless the cause of failure to ignite or loss of ignition is known to be loss of coal in the pulverizer subsystem. In the latter event initiation of the master fuel trip may be omitted but all conditions for proper light-off shall exist before restoring coal feed.

For the next and all subsequent pulverizers placed in operation, failure to ignite or loss of ignition for any reason on any burner shall cause the stopping of fuel flow to that burner. All conditions for proper light-off shall exist before restarting the burner.

(o) After stable flame is established, slowly adjust the air register(s) or damper(s) to their normal operating position, making sure that ignition is not lost in the process.

If the igniters do not meet class 1 or 2 requirements they shall be shut down at this point.

(p) Before starting another pulverizer, the loading on the operating pulverizer shall be at a level that will prevent its load being reduced below its proper operating limit when a second pulverizer is placed in operation.

If an operating pulverizer does not have all of its burners in service it is desirable to start another pulverizer with all burners and shut down the pulverizer and empty it rather than start its idle burners. If ample precautions are taken to prevent (1) accumulation of coal in idle burner lines, (2) hot burner nozzles and diffusers which may cause coking and fires when coal is introduced; and (3) excessive disturbance of fuel-air ratio of the operating burners; idle burners may be started on the first pulverizer without shutting it down. (See also 584)

(q) Follow the same procedure (k through p) when placing the second pulverizer into service. CAUTION: When fuel is being admitted to the furnace, never turn on igniters for any burner without proof that there is a normal fire in the furnace. If the igniters for operating burners have been turned off, then those operating burners must have satisfactory ignition before any igniter is started. A common cause of furnace explosions is the turning on of igniters where there has been a flameout of an operating burner.

(r) After exceeding predetermined minimum main fuel input [See 4123 (d) (2)] the burners should be providing sustaining ignition energy for the incoming fuel. The igniters (Class 1 or class 2) may then be shut off. Verify that the stable flame continues on the main burners after the igniters are shut off. Some systems permit the igniters to remain in service on either intermittent or continuous basis. This is permissible provided the igniters have been tested to meet all the requirements of class 1 igniters or class 2 igniters with proper associated interlocks. [See 4123 (d) (3).] Several explosions have been attributed to reignition of an accumulation of fuel by inadequate igniters after unnoticed flameout of the main burners.

(s) The normal on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed in service until:

(1) A predetermined minimum main fuel input has been exceeded;

(2) All registers on non-operating burners are closed, unless compensated for by the control system;

(3) Burner fuel and air flow are adjusted as necessary;

(4) Stable flame and suitable furnace conditions have been established.

54. Normal Shutdown

541. When taking the unit out of service, bring the boiler down to about 25 percent load.

542. Take the combustion control for normal on-line use out of service (unless designed for shut down procedures) and adjust the fuel input, air flows, and register positions to the values established for start-up.

543. Follow the reverse procedure of that used during start-up, maintaining purge air flow and register settings. Burner registers are left in start-up position, maintaining purge air flow, until all burners are removed from service. A pulverized fuel system shall be shut down in the following sequence:

5431. Determine that there is flame at those burners of the pulverizer to be shut down and place the igniters in service for the burners served by that pulverizer.

5432. Shut off the hot air and open up the cold air to cool down the pulverizer.

5433. When the pulverizer is cooled, stop the feeder and continue operation of the pulverizer with sufficient air flow to empty out and remove all coal from the pulverizer and associated burner lines. For a high storage pulverizer see 2621(k).

5434. When the burner fires are extinguished and the pulverizer is empty, and cool, shut down the pulverizer subsystem.

5435. Close all individual burner line shutoff valves unless otherwise directed by manufacturer's instructions.

5436. Remove igniters from service.

544. As the boiler load is reduced, shut down the remaining pulverizers sequentially as previously described. At some point removing the next pulverizer from service may result in the remaining burners becoming not stable. At this time the igniters on all remaining burners shall be placed in service before any pulverizer is shut down.

545. A purge of the setting shall be accomplished by maintaining an air flow of not less than 25 percent of full load flow for a period of not less than five minutes.

546. Following the purge of the setting, the burner air registers may be closed and the fans may be shut down. It is strongly recommended a flow of air should be maintained through the unit to prevent any accumulation of combustible gases. Leakage of main or igniter fuel into the furnace or windbox shall be positively prevented.

55. Normal Hot Restart

551. When it is desired to restart a unit after it has been bottled

56. Emergency Shutdown — Master Fuel Trip

561. With the initiation of a master fuel trip from any of the emergency conditions tabulated in 5611 and 5612 below, all coal flow to the furnace from all pulverizers subsystems shall be stopped by tripping burner shutoff valves (B) or equivalent. The igniter systems safety trip valve (E), individual igniter valves (G), primary air fans or exhausters, and coal feeders shall be tripped and igniters de-energized. If a furnace inerting system is installed, the inerting system shall be operated simultaneously with the master fuel trip.

Master fuel trips shall operate in a manner to stop all fuel flow into the furnace within a period that will not permit a dangerous accumulation of fuel in the furnace. A master fuel trip shall not initiate a fan trip.

5611. Mandatory Automatic Master Fuel Trips (see Section 6)

(a) Loss of either all induced or all forced draft fans.

(b) Furnace overpressure from tube rupture or other cause.

(c) All fuel inputs zero (see 6232 (c)). See section 631 for required interlocks and trips for individual pulverizer subsystems.

(d) Loss of all flame.

5612. Mandatory Master Fuel Trips With Alarms — not necessarily automatic.

(a) Partial loss of flame sufficient to introduce a hazardous accumulation of unburned fuel. It is strongly recommended that all new installations include provisions for automatically initiating a master fuel trip for this condition. See also 632 for required interlocks and trips for individual pulverizer subsystems.

(b) Failure of the first pulverizer subsystem to operate successfully under the conditions specified in 522 (n) and 63.

(c) Loss of energy supply for combustion control, burner control, or interlock systems.

(d) Excess furnace suction.

562. Recommended Procedure for Purging After an Emergency Trip. If the fans are operating after the trip, continue in service. Do not immediately increase the air flow by deliberate manual or automatic control action. If the air flow is above 25 percent of full load air flow, it may gradually be decreased to this value for a post-firing purge of at least five minutes. If the air flow is below 25 percent of full load volumetric air flow at the time of the trip, it shall be continued at the existing rate for five minutes and then gradually increased to 25 percent of full load air flow and held at this value for a post firing purge of five minutes.

If the trip was casued by loss of draft fans, or draft fans have also tripped, slowly open all dampers in the air and flue gas passages of the unit to the wide open position in order to create as much natural draft as possible to ventilate the setting. Opening fan dampers shall be timed or controlled to avoid excessive positive or negative furnace pressure transients during fan coast-down. Maintain this condition for a period that will result in not less than five changes in volume, but in any case not less than fifteen minutes. At the end of this period, close the flow control dampers and immediately start the fan(s). Gradually increase air flow to at least 25 percent of full load air flow. These limits shall be adhered to unless adequate tests on a specific unit demonstrate satisfactory purging with different values of flow and time.

563. If it is impossible to restart for some extended period of time, a flow of air through the unit to prevent accumulations of combustible gases shall be maintained.

564. Hazards of Residual Coal Charges in Pulverizers and Clearing After Shutdown.

Pulverizers will, on tripping, have a residual charge distributed primarily in the pulverizer, but also in burner piping and nozzles. This accumulation in a hot pulverizer will generate volatiles that are combustible and explosive. The charge will likely be sufficient to change light-off conditions and thus a new start-up procedure is required as discussed in section 565. If there is doubt whether a pulverizer is charged with coal, use the special procedure of 565 for a charged pulverizer.

Because of the possibility of a variable size charge in the pulverizer on random occasions, it may be preferable to always start up each pulverizer and its burners as though they had been shut down charged with coal. Review this question with the pulverizer and burner manufacturer.

It is important to remove the charge of coal from the pulverizer subsystems with minimum delay or to inter them. If the boiler is to be restarted and brought up to load without delay, the pulverizers with a charge and their feeders shall be started in sequence as required by the load in accordance with the procedure described in section 565.

If a delay in load demand is expected or undetermined, but boiler conditions, including completion of boiler purge will permit firing, the pulverizers shall be started and cleared in sequence in accordance with the prescribed procedure. If during this sequence it becomes possible to fire at a rate greater than the capacity of one pulverizer operating within its range of operation for stable flame, one of the pulverizers and its feeder shall be placed in service to help burn the coal being injected from the remaining pulverizers being cleared.

If there is a significant delay before any firing can be initiated and the pulverizers cleared, the pulverizer subsystem shall be inerted. The time delay for inerting will depend on the coal characteristics, pulverizer temperature, and size and arrangement of the pulverizer equipment. The inerting procedure will be prescribed by the pulverizer equipment manufacturer.

If firing cannot be initiated for an extended time period, the pulverizer may be cleaned manually if required, but only after the pulverizers have been cooled to ambient temperature and have been inerted before opening. There is danger of an explosion when opening and cleaning any pulverizer and thus caution is necessary. (See NFPA 85F-1978, Installation and Operation of Pulverized Fuel Systems.)

Regardless of the steps taken, such as inerting or manual cleaning, a pulverizer that has been tripped without being cleared of coal shall be started using the special procedure required for a charged pulverizer.

565. Clearing Procedure For Pulverizers and Fuel Burning Equipment

In order to minimize hazards caused by accumulations within the pulverizer, as discussed in 564, the following procedure shall be used to clear coal from the pulverizing and fuel burning equipment after a master fuel trip or a trip of individual pulverizers.

(a) Isolate all non-operating or tripped pulverizers from the furnace.

(b) Purge the furnace and start up in accordance with 522 (a) through (i) following a boiler fuel trip.

(c) Light the igniters on all burners of the pulverizer to be cleared. After making sure that the ingiters are lighted and are providing appropriate ignition energy for the main burner, start the pulverizing equipment following the equipment manufacturer's recommendation.

(d) Continue to operate the pulverizer until empty, and in a normal condition for shutdown. If boiler conditions will permit a firing rate greater than the capacity of one pulverizer operating within its normal operating range, the first pulverizer should be kept in operation in accordance with 564. If the first pulverizer cannot be left in service, shut it down in the prescribed manner leaving it cool and as free of coal as practical.

(e) Repeat the procedure for all other pulverizers that had been tripped charged with coal. The procedure and operating principles outlined in Section 55 and 564 should be followed.

573. A common emergency may arise due to a raw coal hangup or threatened unstable flame conditions due to wet coal or change in coal quality. This condition is particularly hazardous. Class 1 or class 2 igniters shall be placed in service immediately on all operating burners in order to support ignition. If coal feed to an offending pulverizer subsystem can be restored or adequate ignition energy can be supplied before main burner ignition is lost, the subsystem may be continued in service provided the flame is stable. However, if the main burner flame on any burner of any pulverizer subsystem is extinguished and class 1 igniters are not in operation, then that burner or subsystem shall be shut down in a way that will prevent coal being reintroduced to the furnace in a random manner. Start-up conditions shall be established before coal feed is restored. See sections 224, 24, 2532, 2621 (c), 2633 and 4123 (b).

58931. A fire detected in an operating low-storage pulverizer may generally be extinguished by shutting off the hot air, increasing the raw fuel feed as much as possible and continuing to operate with cold air. If the temperature at the pulverizer outlet does not drop within a few minutes, introduce water into the raw fuel and/or cold air streams. However, the water must be added in such quantities and at such locations as not to cause hangup or interruption of the raw fuel feed nor to stir up any deposits of combustible material. When all evidence of fire has disappeared, shut off the water and the raw fuel feed, allow the pulverizer to run with cold air passing through it for at least 5 minutes to purge the system and minimize any accumulation of water.

58932. In the event the preceding procedure is unsuccessful in extinguishing the fire, one of the two following procedures shall be followed, as specified by the manufacturer's recommendations:

(a) Stop the pulverizer, isolate the system and inert. Avoid disturbing any accumulation of dust within the pulverizing equipment. Do not open any access doors to the pulverizer until the fire is extinguished and all temperatures have returned to ambient. After isolation of the pulverizer is verified, then follow procedures outlined in 5895, or

(b) Shut off the feeder and allow the pulverizer to clear itself of fuel. Maintain a flow of cold air through the pulverizer until all evidence of fire has disappeared. When the pulverizer is cold, shut it down. Isolate the pulverizer and follow procedures outlined in 5895.

5894. If fire is found in a pulverizer which is out of service, keep out of service, isolate pulverizer, and shut off all air supply to the pulverizer and inert. Do not open any access doors to a pulverizer until the fire is extinguished and all temperatures have returned to ambient and isolation verified.

5895. Following fires in pulverizing systems the pulverizing equipment shall be internally inspected and all coke formations and other accumulations shall be removed to avoid future fires, and if pulverizer is wet, it shall be dried. In no case shall a compressed air jet be used.

615. The design of an interlock system shall be predicated on the following fundamentals:

(a) Supervise starting procedure and normal operation to insure safe operating practices and sequences.

(b) Trip off the minimum amount of equipment in the safest sequence upon reaching conditions that jeopardize the safety of personnel or equipment.

(c) Leave all the equipment running, which safety will permit, to allow quick restoration of service.

(d) Indicate the initiating cause of the trip and prevent starting any portion of the process until safe conditions are established.

(e) Coordinate the necessary trip devices into integrated system.

(f) Where automatic equipment is not available to accomplish the intended function, provide sufficient instrumentation to enable the operator to complete the safe operating sequence.

(g) Retain in the design as much flexibility with respect to alternate modes of operation as is consistent with safety.

(h) Provide for proper preventive maintenance.

(i) Insofar as it is practical, will not require nor permit any manual "defeating" of an interlock in order to start or operate equipment.

(j) Whenever a safety interlock device has to be removed from service, this action shall be annunciated and noted in the log, and a manual or other means shall be substituted to supervise this interlock function.

(k) Where the master fuel trip is directly involved sensing elements independent of control alarm devices and circuits are required. However, reliable individual burner flame failure systems may also be used for initiating master fuel trip systems. These devices shall be suitable for the environment in which they will be located particularly devices applied to fuel equipment and burner fronts.

(l) Prevent misoperation on interruption and restoration of the interlock power supply.

623. Interlocks (See Figure 7)

6231. Figure 7 shows the required system of interlocks which will provide the basic furnace protection for a pulverized fuel-fired multiple burner boiler-furnace operated in accordance with this Standard. The Fuel Trip System is shown in block form.

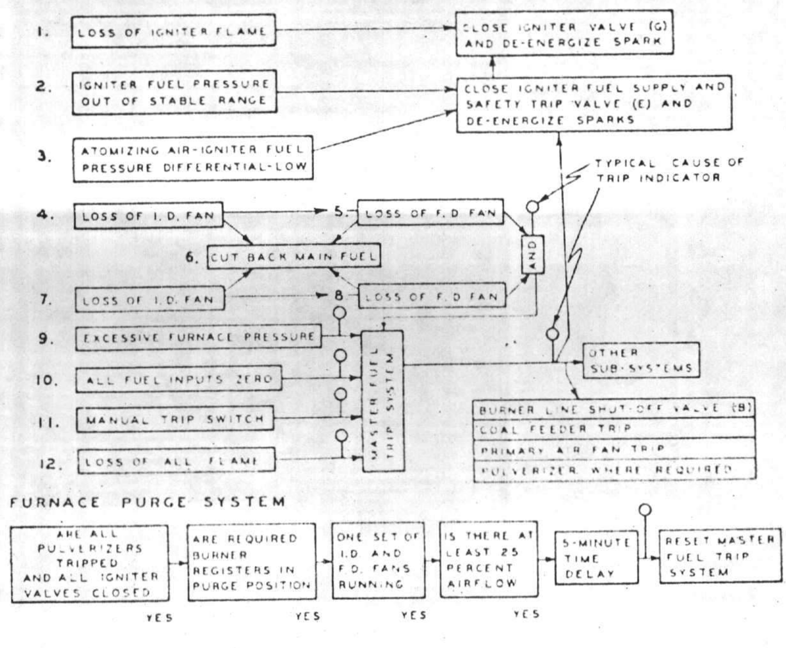

Fig. 7 Block Diagram for Furnace Protection Interlocks for Pulverizers and Igniters.

(a) Block No. 1 shows loss of an individual igniter flame which shall be interlocked to close its individual igniter shutoff valve (G), and de-energize the spark.

(b) Block No. 2 represents unsafe conditions caused by high-low igniter fuel header pressure which shall be interlocked so as to initiate the tripping of the igniter main fuel supply (E) and individual igniter valves (G) and de-energize sparks.

(c) When light oil is used for ignition fuel with air (or steam) atomization, lack of sufficient air-ignition oil pressure differential resulting either from low air or high oil pressure is an unsafe condition which will trip the igniter main fuel supply (E) and individual igniter valves (G) and de-energize sparks as indicated by Block No. 3.

(d) In the event that an igniter is required to maintain stable flame of an associated main burner and tripping of main fuel from loss of flame is not provided, additional interlocks shall be provided

631. Mandatory Automatic Pulverizer Subsystem Trips. A direct fired pulverized coal system shall be interlocked so that:

(a) Failure of primary air fan or exhauster trips burner shut off valve or equivalent and feeder. Follow manufacturer's requirements regarding pulverizer tripping.

(b) Failure of pulverizer trips feeder.

(c) Failure of feeder alarms, and restarting is blocked until feeder startup conditions are re-established.

632. Mandatory Pulverizer Subsystem Trips — Not Necessarily Automatic.

(a) Loss of igniters or adequate ignition energy during the startup of a pulverizer trips that pulverizer subsystem.

(b) Loss of individual burner flame trips that burner or its pulverizer subsystem. (See 534.)

(c) Loss of coal feed to the burners of a pulverizer subsystem trips the feeder unless class 1 igniters are present to ignite any credible flammable input from this subsystem. Before restarting the feeder establish the conditions under which the igniters will ignite the input. (See 573.)

Several means are available to indicate loss of coal feed to the pulverizer, loss of coal stored within the pulverizer, and loss of coal input to the burners. At least one of these means but preferably a combination shall be reliably established and used to actuate loss of coal trips either manual or automatic.

633. Mandatory Sequential Starting Interlocks. Permissive sequential interlocking shall be arranged so that the pulverizer subsystem can be started only in the following sequence:

(a) Igniters for all of the burners served by the pulverizer in service and proven.

(b) Start primary air fan or exhauster.

(c) Start pulverizer.

(d) Start raw coal feeder.

721. Required Alarms.

In addition to the safety features of the interlock system, the separately annunciated alarms in 721 (a) through (m) shall be provided.

(a) Ignition Atomizing Steam or Air-Oil Pressure Differential (Lo)

When igniters require steam or air atomization, an alarm shall be provided to warn that the differential between steam or air pressure and oil pressure is below normal operating range and that poor oil atomization may result.

(b) Ignition Fuel Header Pressure (Hi and Lo)

The ignition fuel header pressure shall be monitored as close to the burners as possible in order to warn the operator of high or low pressure in advance of conditions which lead to a trip.

(c) Pulverizer Tripped

Alarm when pulverizer is tripped (not normal shutdown).

(d) Primary Air Fan Tripped

Alarm when primary air fan is tripped. (not normal shutdown)

(e) Coal Stoppage to Pulverizer

Alarm when the feeder is running and the coal detecting device indicates no coal flowing or when the feeder trips (not normal shutdown).

(f) Coal-Air High Temperature

Alarm when coal-air temperature within or at the pulverizer outlet exceeds normal operating limits.

(g) Furnace Pressure (Hi)

This shall be measured near the normal furnace pressure tap location. It shall warn the operator of a pressure, in excess of normal operation, and an approach to trip conditions.

(h) Furnace Draft (Hi)

For balanced draft operation. This shall be measured near the normal furnace draft tap location. It warns the operator of a draft, in excess of normal operation and an approach to trip conditions.

(i) Loss of Operating FD Fan

This shall be sensed and alarmed only when the fan is supposed to be running and is not.

(j) Loss of Operating ID Fan

For balanced draft furnace operation. This shall be sensed and alarmed only when the fan is supposed to be running and is not.

(k) Furnace Air Flow (Lo)

This shall be sensed and alarmed when total air flow falls below 25 percent of full load volumetric air flow.

(l) Loss of Interlock Power

This shall be sensed and alarmed and shall include all sources of power required to complete interlock functions. For example, if both a 125VDC electric circuit and a compressed air circuit are required for an interlock scheme, then loss of either shall be annunciated separately.

(m) Loss of Control Power

This shall be sensed and alarmed to include all sources of power for the combustion control system.

(n) Loss of Flame

Partial or total loss of flame "envelope" still receiving fuel shall be monitored and alarmed so that an evaluation can be made as to whether or not a hazardous condition exists in the furnace. (See 5612 (a).)