Babcock Power

Technical Publication

World-Proven Coal Pulverizer Technology Debuts in the U.S.

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RST-99

WORLD-PROVEN COAL PULVERIZER TECHNOLOGY DEBUTS IN THE U.S.

ABSTRACT

Fuel changes, typically driven by fuel availability, economics, or emissions compliance considerations, can adversely affect performance of existing PC-fired boilers and associated fuel preparatory systems.

This paper discusses the background of one such fuel change, operational effects thereof, and events leading ultimately to Riley Stoker Corporation's (RSC) application of new-to-the-U.S.A. vertical spindle coal pulverizers for Omaha Public Power District's (OPPD) boiler and fuel system retrofit project on OPPD's North Omaha Station 225 MW, #5 unit.

Included is a description of the fuel system, pulverizer, and auxiliaries supplied by RSC, and operational results following the retrofit.

Pulverizer system performance data, responsiveness to unit demand changes, and effects on boiler load capability, boiler efficiency, and emissions are discussed and evaluated.

INTRODUCTION

OPPD'S North Omaha Station Unit No. 5, having a gross generating capacity of 225 MW, began commercial operation in 1968. Unit 5's steam generator, a Foster Wheeler (FW) single reheat, natural circulation unit having a pressurized front wall-fired furnace, had a continuous steaming rate of 1,502,000 #/hr at 2591 psig and 1005°/1005°F, while firing either natural gas or a Kansas > 5% sulphur bituminous coal with a heating value (HHV) of 11,380 Btu/lb. The coal's ultimate analysis is shown in Figure 1.

The original fuel system consisted of three spring-loaded, MB type, vertical spindle mills, each with gravimetric belt feeder, seal air fan, 1800 rpm primary air fan, and four mill outlets supplying pulverized coal to one of the three horizontal rows of (4) dual-fuel burners. When operating at boiler MCR, each mill had a coal throughput of approximately 53,000 #/hr. Specified product fineness was 70% thru 200 mesh and 98% thru 50 mesh.

Diminishing supply of the original Kansas coal forced OPPD to gradually transfer in 1975-76 to a low sulphur, moderate moisture, Southern Wyoming Hanna Basin coal, Rosebud seam, having a heating value 9-13% below that of the original coal; analysis is shown in Figure 2. This fuel change did not affect Unit 5's load carrying capability. Then during 1983-84, OPPD began procurement of a significantly lower cost Wyoming Powder River Basin coal for their two coal-fired plants. This coal, having low sulphur, a relatively low ash fusion temperature, high moisture, and an attendant reduced heating value, had an immediate and profound effect on North Omaha Station's No. 5 Unit. For coal and ash analyses, refer to Figure 3. The fuel's lower ash fusion temperatures, ash alkali make-up, and higher gas weights caused a forced reduction in boiler generating capacity due to excessive upper furnace slagging, back-end fouling and tube metal overheating. The maximum continuous steaming rate was administratively reduced to about 800,000 #/hr; a reduction of ~ 47%.

This operating level was expected to be sufficient to meet OPPD's load demand until approximately 1991. Future load growth projections indicated that system generation requirements would then economically support a boiler refurbishment to more adequately utilize the in-use compliance fuel.

Likewise, the fuel system was adversely affected, although not to the point of limiting unit output due to the already imposed substantial boiler derate. If, however, subsequent boiler changes were effected to permit higher outputs, the fuel system, particularly the mills, because of their deteriorated condition, would quickly become the load-limiting factor. An OPPD mill evaluation determined that mill replacement was essential for future Unit 5 operating reliability.

OPPD AT A GLANCE

Omaha Public Power District (OPPD), a political subdivision of the State of Nebraska, began operations as a Public Utility in 1946. It is governed by an eight member board of directors elected to six-year terms from districts in OPPD's service area.

Through ownership of all it's generating, transmission and distribution facilities, OPPD, with its 2500 employees, serves a population of almost 600,000 in 13 counties located in southeastern Nebraska - an area of 5000 square miles.

OPPD's current total generating capacity of over 1800 MW is derived from two coal-fired plants, one nuclear plant, and four gas-turbine peaking units. As a charter member of the Mid-Continent Area Power Pool (MAPP), comprised of 43 utilities, OPPD's power transmission is extended to nine upper midwestern states and central Canada.

Accordingly, OPPD issued in 1989, a specification and RFP for refurbishing North Omaha Station's Unit #5 boiler and fuel system to regain lost unit capacity. Some specific changes and constraints were identified, namely:

- Replacement of certain boiler sections
- Repairs to certain boiler sections
- Boiler modifications limited to the existing boiler envelope
- All equipment changes confined to the existing support structure
- New pulverizers
- New seal air system
- New primary air fans

For this Unit 5 refurbishment, Riley proposed boiler modifications which would achieve a continuous rating of 1.1×10^6 # stm/hr (guaranteed) and a projected continuous rating of 1.2×10^6 # stm/hr. Accordingly, the fuel system had a design basis for the 1.1×10^6 boiler rating but with operating capability exceeding a boiler rating of 1.2×10^6 #/hr.

The mill offered was a medium speed vertical spindle type, or more specifically, a ring-roller "MPS" design as built by Deutsche Babcock Werke (DBW) in Oberhausen, Germany. Its origin dates to 1958 when Gebruder Pfeiffer of Kaiserslautern, Germany, developed the MPS mill's unique roller loading arrangement as a modification to its MB mill predecessor. Shortly thereafter, DBW became the first licensee of Gebruder Pfeiffer in Europe for coal applications.

This particular mill was chosen because of DBW's successful track record - not only in their world-wide installation of 6 to 100 TPH MPS coal mills since the early 1960s - but also in their implementation of many innovations and mill improvements over the years. Such enhancements made these mills ideally suited for the cyclic duty of this station.

Subsequently, in April 1990, OPPD awarded to RSC the Unit 5 retrofit contract with completion scheduled for end of April 1991.

FUEL SYSTEM DESCRIPTION

To refurbish the fuel system, Riley provided three Deutsche Babcock, MPS-170 mills, each with a nominal capacity of 63,000 #/hr; three, 1200 rpm radial-bladed primary air fans; two - 100% capacity seal air fans; three mass flow air meters; and miscellaneous auxiliary equipment. The system schematic is shown in Figure 4.

Aside from the mill and PA fan replacements, use of a common seal air system with two 100% capacity fans, and mass flow meters for primary air measurement and control represented other notable changes to the original fuel system. Foundations were replaced to accommodate the new PA fans and mills, which were positioned to align with existing ducting, piping, and pyrite sluicing systems. The new seal air fans were located remotely from the mill bay and sized to provide seal air to the mills, feeders, and PA fans. This seal air fan utilization enabled elimination of an existing separate feeder seal air system. Existing coal piping and coal/gas burners were not changed.

Figure 5 shows the general arrangement of the fuel system.

MPS 170 Mill Supply

Each of the three MPS 170 mills is equipped with a 400 HP direct-coupled drive motor; a removable planetary gear reducer containing a hydrodynamically lubricated, tilting-pad type thrust bearing; a separate duplex motor/pump/filter lubricating console with heater, cooler, and instrumentation; a separate roller-loading hydraulic console with filters, accumulators, directional valving, reservoir, and instrumentation; three hydraulic roller-loading cylinders with accumulators; seals, seal air connections, steam inerting connections; and numerous hinged and peripherally bolted doors for inspection, access, and maintenance.

The mill supply included all necessary special tools and fixtures for minor mill maintenance as well as major mill overhauls, along with a carriage-mounted mill turning gear assembly with electric motor drive and flexible coupling for attachment to the mill motor's double ended shaft.

MPS 170 Mill Description (See Figure 6)

The MPS mill is classified as an air swept, applied force, vertical spindle, medium speed, ring and roller mill having integral classifier, grinding, and base sections and designed for pressurized operation. In the grinding section, three fixed-axis rollers rotate on a segmentally-lined grinding table supported and driven by a planetary-type gear reducer, which is direct-coupled to a squirrel cage induction type drive motor. Equal grinding force is applied to each of the three grinding rollers by a guide frame connected by vertical tension rods to three hydro-pneumatic cylinder loaders secured to the mill foundation.

Coal is metered and gravity fed through a central feed pipe to the grinding table where it flows outwardly by centrifugal action and is ground between the rollers and table. Metered hot air for drying and coal transport enters the base housing and flows upward through a stationary swirl ring having multiple sloped nozzles surrounding the rotating grinding table. The air mixes with, and dries coal in the grinding zone and carries the pulverized coal particles upward into a centrifugal, double cone-type classifier (Type SLK) having multiple adjustable inlet swirl vanes. A vertical annular outlet surrounding the central feed pipe allows fine pulverized coal to exit the classifier and enter a mill discharge chamber, connected to multiple coal pipes leading to the boiler. Oversized coal particles spiral down the classifier inner cone and discharge back into the grinding zone for further grinding through multiple-hinged reject doors located at the base of the cone.

Pyrites and extraneous dense materials fall through the nozzle ring onto the base section top plate where they are swept, by two scraper blades attached to the grinding table yoke, into the pyrite discharge chute and water-filled collection hopper located below.

Fuel System Design Considerations and Goals

An uncertain boiler steam flow upper limit for the modified boiler imposed a challenge in fuel system equipment sizing. Although capacity and performance guarantees were based on a steaming rate of 1,100,000 #/hr (63,000 # coal/hr/mill) the fuel system needed to accommodate at least the predicted continuous steaming rate of 1,200,000 #/hr (68,000 # coal/hr/mill) and have margin to allow for the possibility of still higher steam flows. Conversely, physical constraints in the mill bay as well as the decision to utilize existing coal piping, placed a practical size limitation on replacement equipment.

With these considerations at hand, each mill system was designed to potentially deliver up to 80,000 # coal/hr, which would produce a boiler steaming rate of over 1,400,000 #/hr. At this maximum rating, however, mill product fineness would fall below OPPD's specified value of 75% thru 200 mesh, although likely maintaining the specified thru 50 mesh fineness of $\geq$ 98%. Also, coal pipe velocities would become excessive (> 100 FPS), even for the plant's relatively non-abrasive sub-bituminous coal.

Therefore, a practical continuous pulverizer system output, operating under optimum conditions, was established at 68,000 #/hr. Accurate metered control of both coal and primary air (per the characterization shown in Figure 7) with sufficient coal/air mill exit temperature (140°F), was expected to eliminate a number of past fuel system deficiencies such as:

- Low mill product fineness
- Little mill turn-down capability
- Utilization of maximum available primary air at all mill loads (to avoid mill roller skidding)
- Abnormally high coal pipe wear (excessive coal pipe velocity)
- Low windbox pressure
- Poor mill response to changes in load demand
- Poor combustion (LOI in ash 14-20%)

To control the air/fuel characterization shown in Figure 7, and provide accelerated response to mill system demand, as well as protection against mill overloading, RSC employed the three controller analog control system shown in Figure 8. This system features auto or manual operation of air and coal with bias adjustment available on each, and rate action on both the feeder and air flow controllers to accommodate sudden demand changes. The mill differential controller provides automatic coal feeder run back, whenever mill pressure differential reaches a preset abnormally high value. This feature is designed to prevent mill pluggage under unpredictable mill upset conditions.

Likewise, DBW's optional hydro-pneumatic roller loading system was employed to afford maximum mill operating flexibility and responsiveness to changes in load demand. This system features not only an adjustable characterization of grinding force with coal feed rate, but permits lifting grinding rollers off the grinding dish to provide low power mill start-ups with no metal-to-metal contact, and equally low power start-ups with a coal-laden mill. The grinding force-to-mill load characterization established by RSC is shown in Figure 9.

This characterization is accomplished by comparing a function of the coal feeder speed output to the hydraulic system back pressure; refer to Figure 10. Through proportional and reset action,· the hydraulic system's output control valve is adjusted to match grinding force with feeder speed. Another feature of this system is to automatically bias the grinding force upon deviation of mill grinding zone pressure differential from the preset value established as a function of mill load (feeder speed); See Figure 11.

Mill outlet air/coal temperature is measured at each mill's classifier exit and, through proportional and reset action, is controlled to a predetermined set point by adjusting positions of both the hot and tempering air dampers; this control schematic is shown in Figure 12.

For seal air admittance and control to each mill, and affiliated equipment, a differential control valve, located in each mill's seal air supply line, regulates to a prescribed differential pressure between the mill's seal air ring header and primary air duct at the entrance to the mill.

Past high MB mill maintenance costs prompted OPPD to specify a mill grinding component wear life of 100,000 hours, and application of ceramic linings in expected high wear areas in the mill.

For the latter requirement, ceramic linings were applied to the following surfaces:

- Impact side of the roller thrust brackets
- Complete inside surface of the grinding housing
- Inside surface of the classifier inner cone
- Head surface and spool pieces of the mill discharge chamber.

And the 100,000 wear life requirement was guaranteed by RSC albeit with allowance made for this rather ambitious achievement.

Another OPPD concern was the high incidence of mill fires with the current fuel. Accordingly, a steam inerting system was specified for the new mills. RSC, in turn, provided the necessary valves, piping, and mill connections and developed the procedures for admission of steam during critical stages of mill start-ups and shutdowns.

OPERATING RESULTS

With the No. 5 boiler and fuel system modifications in place, coal firing began, as scheduled, in May of 1991. After a brief shakedown period, RSC performed preliminary performance tests, and in late June, OPPD conducted contract performance and capacity tests.

Because mill product fineness values from the preliminary tests far exceeded those contract-specified (See Figure 13), OPPD opted not to include further fineness testing in their unit performance and capacity tests. For the subsequent performance and capacity tests run at boiler steam flow rates of 1,135,000 and 1,208,000 #/hr, average coal throughput rates per mill were 64,000 and 68,300 #/hr. This compared favorably with RSC's predicted coal flow values of 63,000 and 68,000 #/hr for 1,100,000 and 1,200,000 #/hr steam flows.

A significant finding in these tests was the boiler's unprecedented low level loss-on-ignition (L.O.I.) in both the fly ash and bottom ash. A comparison with pre-modification values follows:

	Before Mods	After Mods
Bottom Ash - %	20	0.63
Fly Ash - %	14	0.77

Based on an assumed 80% fly ash/20% bottom ash distribution, these L.O.I. values equate to the following boiler efficiency combustible losses:

	Before Mods	After Mods
Unburned Carbon Loss - %	~ 1.5	~ 0.05

Boiler efficiency, as calculated from the 1,135,000 #/hr steam flow test data, was 86.39%. Adjustments for design fuel properties, air inlet temperature, and air heater leakage yielded a corrected boiler efficiency of 85.73%. This compares with OPPD's 1989 corrected efficiency on #5 boiler of 84.19% at a boiler steaming rate of 817,450 #/hr.

Because little formal testing was required or performed, the bulk of available mill system operating data was obtained during normal day-to-day unit operation in July and August of this year. Typical 24 hour Unit 5 operation to meet OPPD's summer load demand, included a daytime maximum load of ~ 185 MW gross (boiler steam flow - 1.2×10^6 #/hr) and a late night/early morning load of 70 MW gross (boiler steam flow - 0.5×10^6 #/hr). Over this load range, all three mills are normally kept in operation under full automatic control without burner supporting fuel. Figures 14 and 15 depict typical fuel system data at the maximum and minimum loads, respectively. From these and other intermediate load data, mill pressure loss and specific power consumption characteristic curves for both mills and PA fans were developed as shown in Figures 16 thru 19.

Other qualitative findings during the first few months of mill operation are noted as follows:

- Use of steam inerting during periods of mill start-up and shutdown required some modification in timing, automation, and duration, to where it provided the intended safety of operation without undesirable side effects.

- As designed, the hydraulic roller loading system effectively raised grinding rollers from the grinding dish for both empty and coal-laden mill start-ups. Then, when activated, quickly lowered rollers to their grinding position, and automatically applied a roller loading force proportional to coal feeder speed.

- Air/coal characterization as shown in Figure 7 proved satisfactory at all mill loads, yielding good mill performance, while enabling control of mill outlet temperature to the prescribed set point.

- After some early calibration problems, the primary air mass flow meters demonstrated reliability, repeatability, and provided tight control of the air-to-coal relationship.

- Rapidity of mill response to changes in load demand was so great that some control detuning was necessary.

DISCUSSION

As the operating data illustrate, having a well performing pulverizer and a tightly and correctly controlled fuel system can greatly improve the boiler's combustion process - without the need for burner modifications or replacement. In this case, the indicated boiler efficiency increase of over 1.5% yields an annual savings - in fuel cost alone - of almost $100,000.

At maximum mill loading - which incidently reflects a coal feeder output limitation imposed long ago by OPPD to protect the previous mills from overloading and skidding - excellent grinding efficiency of this MPS 170 Mill is evident by its specific power consumption of ~ 4.5 kw/ton (Ref. Figure 17).

Pulverizer pressure loss (Ref. Fig. 16) at a coal throughput of 68,000 #/hr agrees well with predicted values whereas low mill load ΔP is less than expected.

From all indications, the boiler could operate continuously at steaming rates exceeding the present ~ 1.2×10^6 #/hr level, restricted, in turn, by the previously noted coal feeder capacity limitation. OPPD plans to reprogram their distributed control system for higher coal feed rates, thusly removing the existing fuel system output cap.

Pulverizer sub-systems, namely: the planetary gear reducer, its supporting lube oil system, and the hydraulic loading system have performed well with only minor instrumentation difficulties encountered.

Although not quantified, use of simultaneous feedforward load demand signals to primary air, coal, and grinding pressure final controlling elements, resulted in excellent MPS mill response. In fact, the milling system response exceeded the boiler's rate-of-change capability.

For the high volatile sub-bituminous coal used at No. Omaha Station, mill steam inerting has demonstrated its suppression effectiveness when used judiciously.

Project Overview

The purpose of the Unit #5 refurbishment was to better utilize compliance fuel, to replace worn out equipment, and to meet future load growth requirements. All these factors were necessary to attain OPPD's corporate goal of providing dependable and economical power for their customers/owners.

The project was successful in achieving the above goals and was completed on schedule and under budget (approx. $300/kw).

Future MPS Mill Installations

Effective October 1, 1990, Riley Stoker Corporation became a wholly-owned U.S. subsidiary of Deutsche Babcock Werke. This relationship gives RSC close technical ties to DBW and the opportunity to offer MPS mills on future new or retrofit projects, both in the U.S. and abroad.

Such future installations could include some or all of the optional MPS mill design features developed by DBW. One additional feature to that employed in this initial U.S. installation is that of a rotating classifier, designated type "SLS". This classifier has demonstrated vastly improved - and controllable - sharpness of classification as shown in Figure 20. This capability will enable optimization of product fineness for low NO_x, off-stoichiometric combustion, and have the potential to increase pulverizer capacity by minimizing the overgrinding of acceptably sized coal particles.

REFERENCES

Omaha PPD Specification Documents No. 1677
Refurbishment of Unit No. 5
At the North Omaha Station - 1989

North Omaha Station Unit No. 5
Steam Generator Performance Test
By Technical Services, August 22, 1991

OPPD Results Department Records

Deutsche Babcock Test Report
SLS 212 Vane Type Classifier
August, 1989

RSC Service Department
Daily Operating Reports
May - September, 1991

FUEL ANALYSIS
KANSAS BITUMINOUS

Ultimate Analysis (%) - As Received

Carbon	-	61.73
Hydrogen	-	4.39
Sulfur	-	5.24
Oxygen	-	3.09
Nitrogen	-	1.15
Moisture	-	7.70
Ash	-	16.70
HHV (Btu/lb)	-	11,380
	-	
HGI	-	55

FIG. 1

FUEL ANALYSIS
SOUTHERN WYOMING - HANNA BASIN BITUMINOUS
ROSEBUD SEAM

Ultimate Analysis (%) - As Received

Carbon	-	61.00
Hydrogen	-	4.25
Sulfur	-	1.15
Oxygen	-	9.57
Nitrogen	-	1.33
Moisture	-	13.20
Ash	-	9.50
HHV (Btu/lb)	-	10,500
HGI	-	50

Fusion Temperature of Ash (°F)

	Oxidizing	Reducing
Initial	N.A.	2200
Softening	N.A.	2260
Hemispherical	N.A.	2280
Fluid	N.A.	2350

Mineral Analysis of Ash (%)

P_2O_5	0.79	CaO	13.36
SiO_2	42.00	MgO	2.46
Fe_2O_3	7.09	SO_3	9.64
Al_2O_3	21.63	K_2O	1.46
TiO_2	0.87	Na_2O	0.33

Undetermined - 0.37

FIG. 2

FUEL ANALYSIS
WYOMING POWDER RIVER BASIN SUB-BITUMINOUS
RAWHIDE SEAM

Ultimate Analysis (%) - As Received

Carbon	-	47.51
Hydrogen	-	3.53
Sulfur	-	0.35
Oxygen	-	11.86
Nitrogen	-	0.53
Moisture	-	30.79
Ash	-	5.43
HHV (Btu/lb)	-	8115
HGI	-	67

Fusion Temperature of Ash (°F)

	Oxidizing	Reducing
Initial	2155	2080
Softening	2196	2117
Hemispherical	2212	2138
Fluid	2290	2198

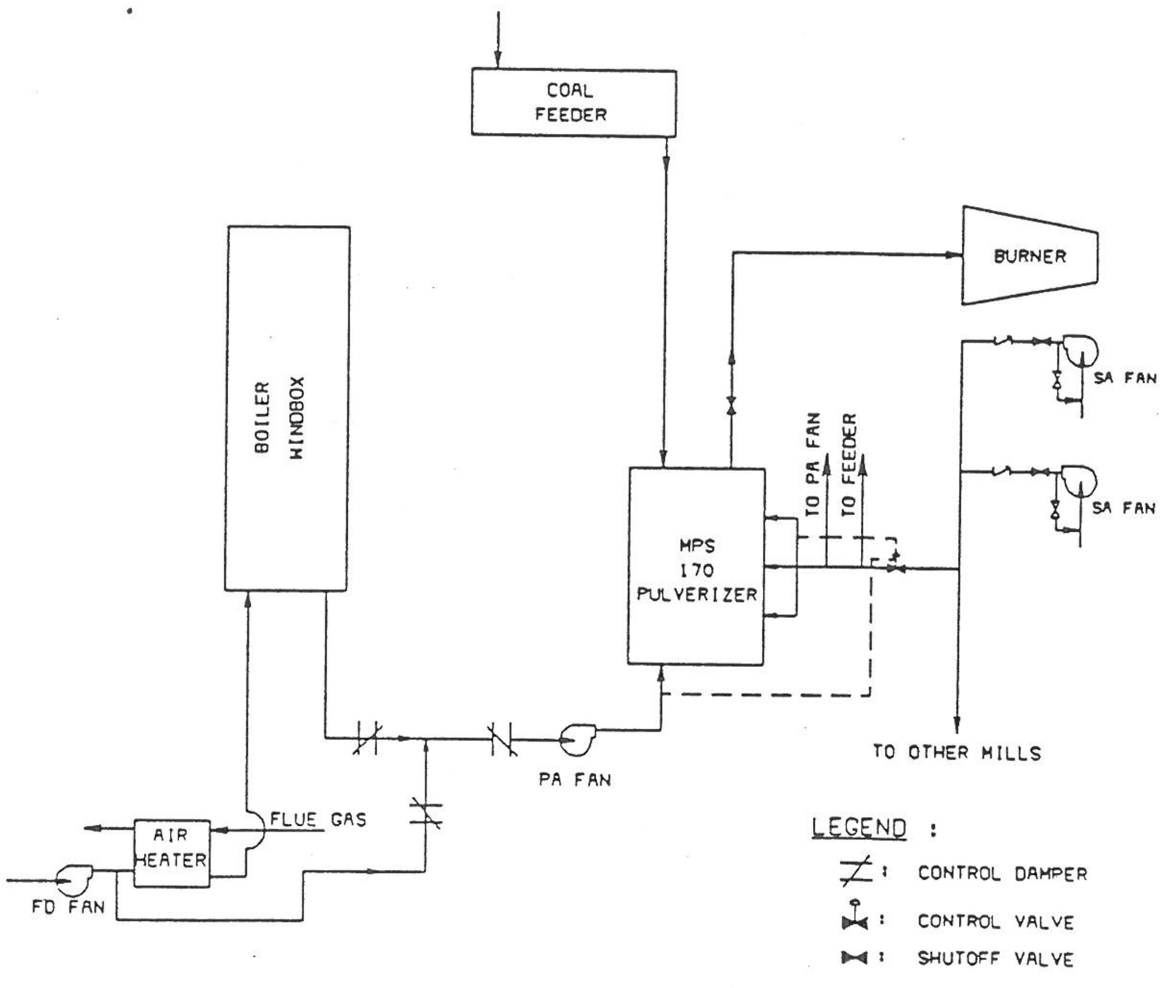
Mineral Analysis of Ash (%)

P_2O_5 - 0.90	CaO - 20.78	MgO_2 - 0.05
SiO_2 - 37.00	MgO - 4.73	BaO - 0.55
Fe_2O_3 - 4.66	SO_3 - 11.30	SrO - 0.41
Al_2O_3 - 14.40	K_2O - 0.48	
TiO_2 - 1.41	Na_2O - 1.48	

Undetermined - 1.85

FIG. 3

OMAHA PPD
NO. OMAHA STATION #5
FUEL SYSTEM
PROCESS FLOW SCHEMATIC



M1836A

FIG. 4

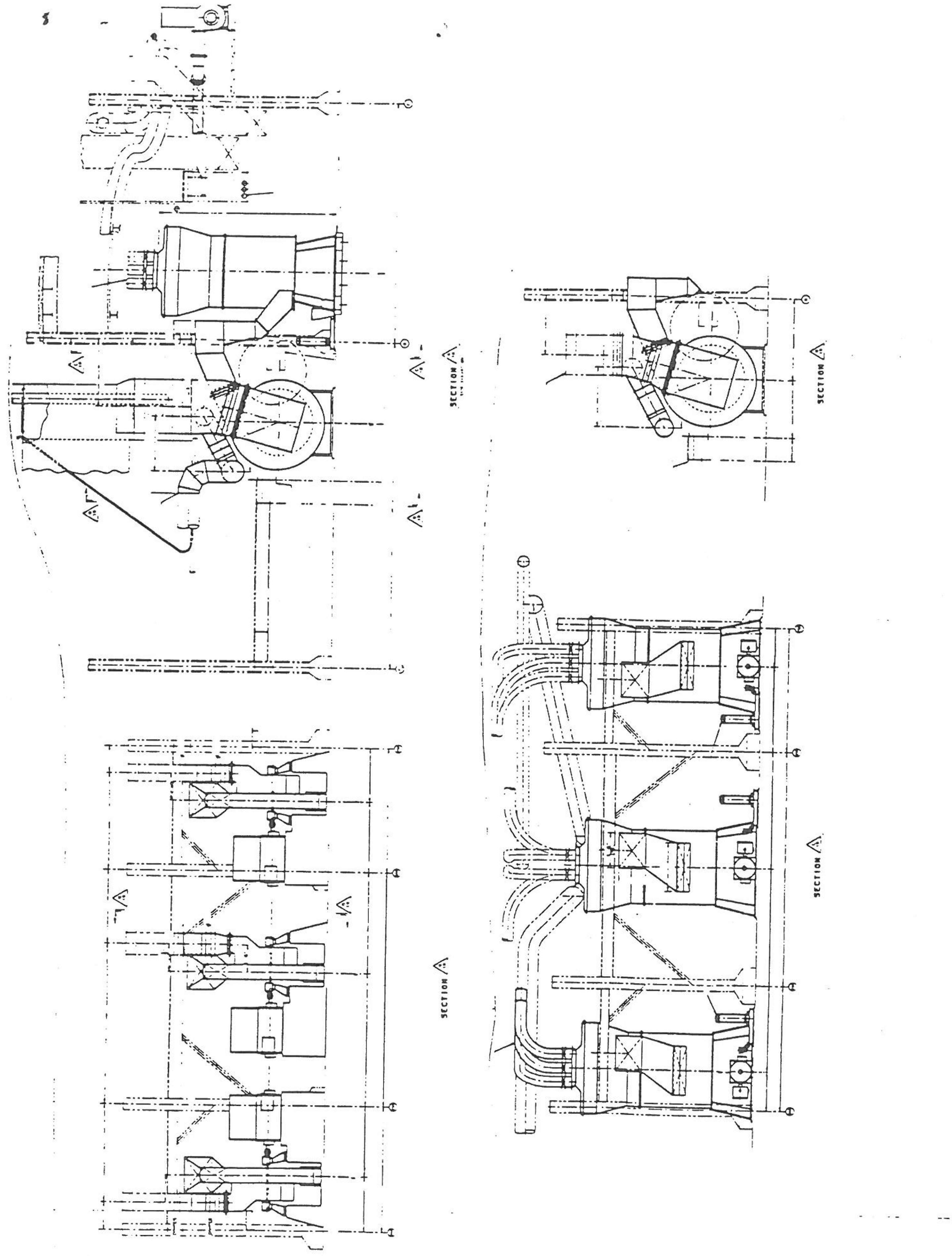
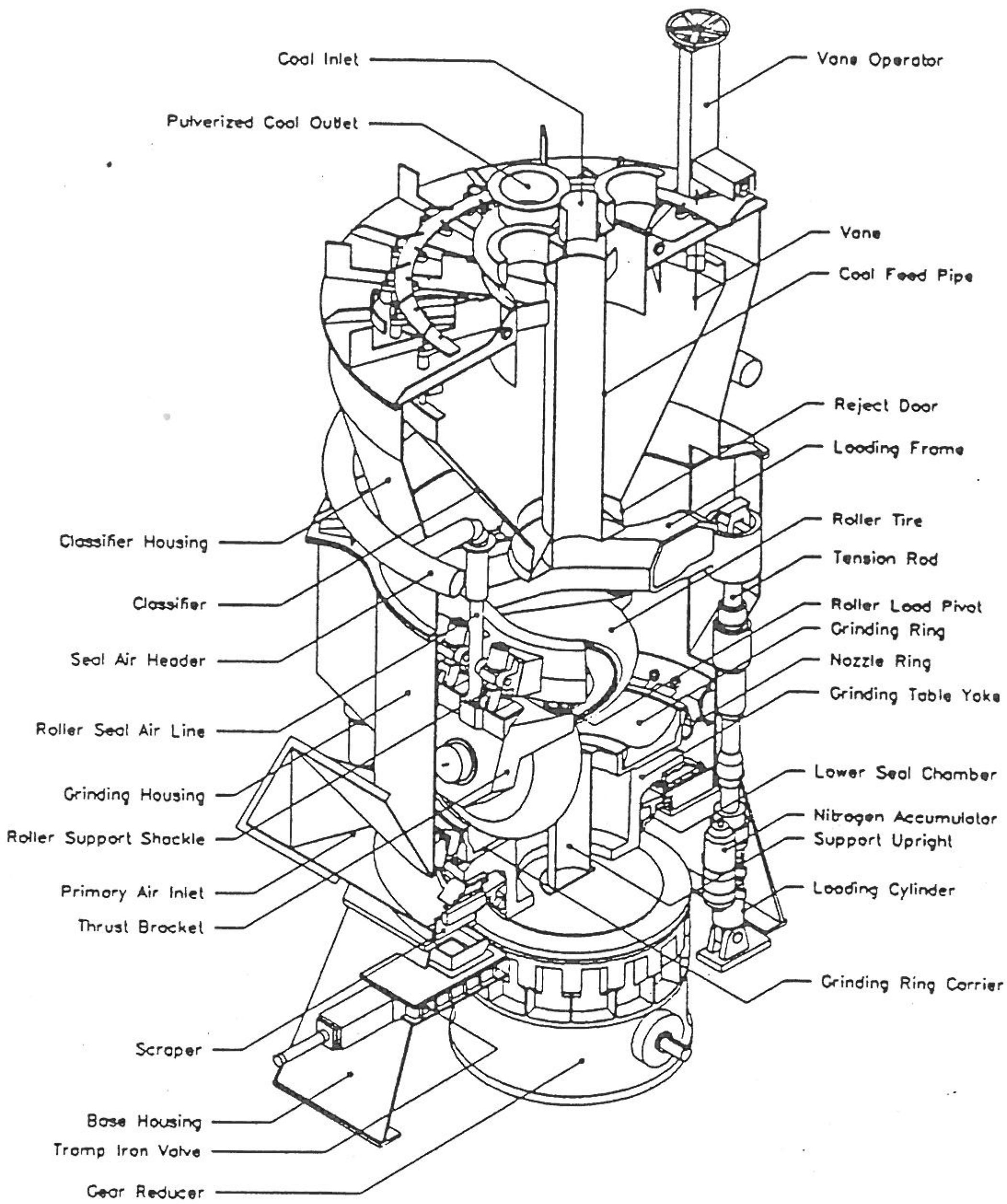


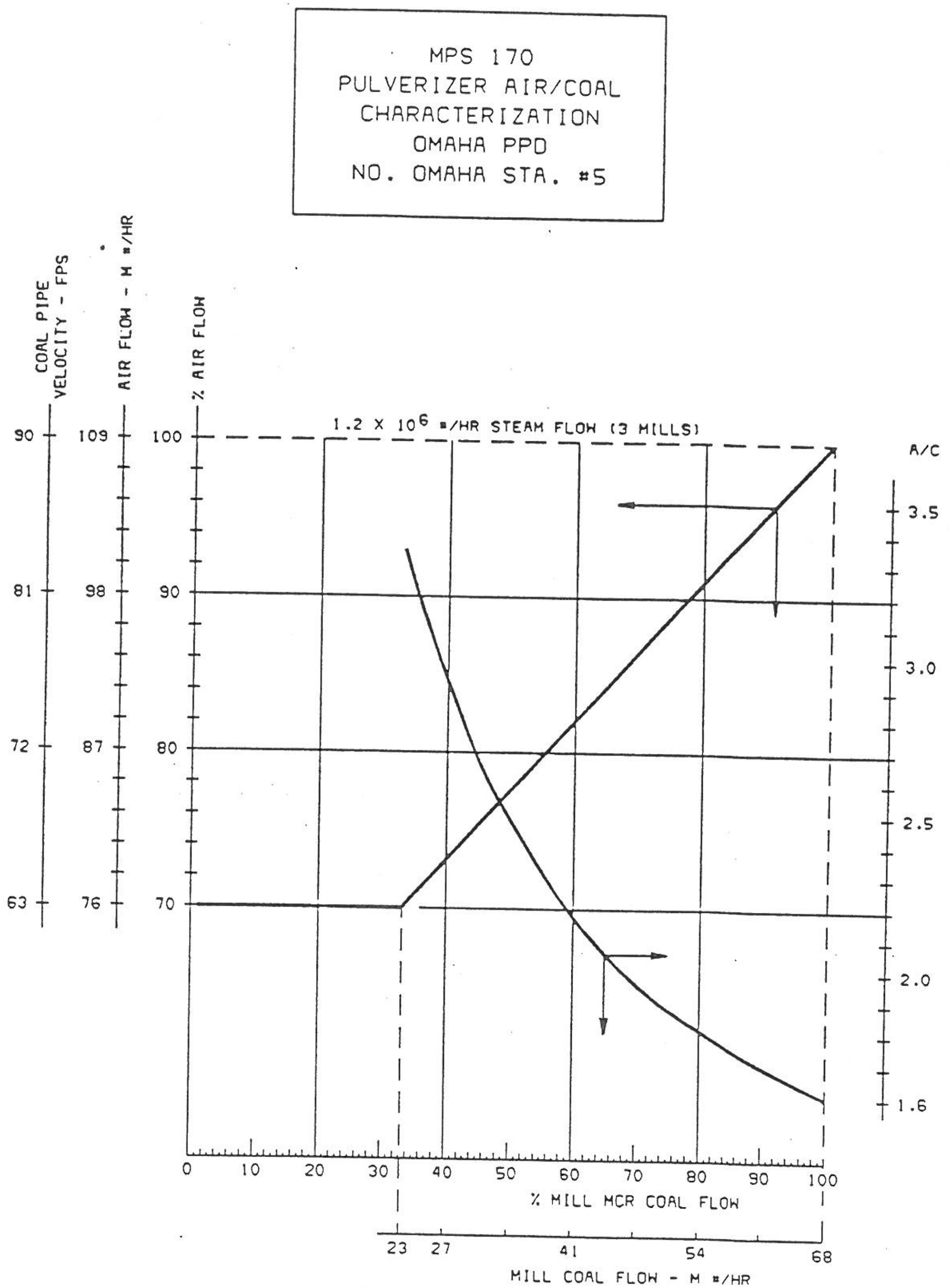
FIG. 5



Type MPS Roller Mill – Model 170

M1842

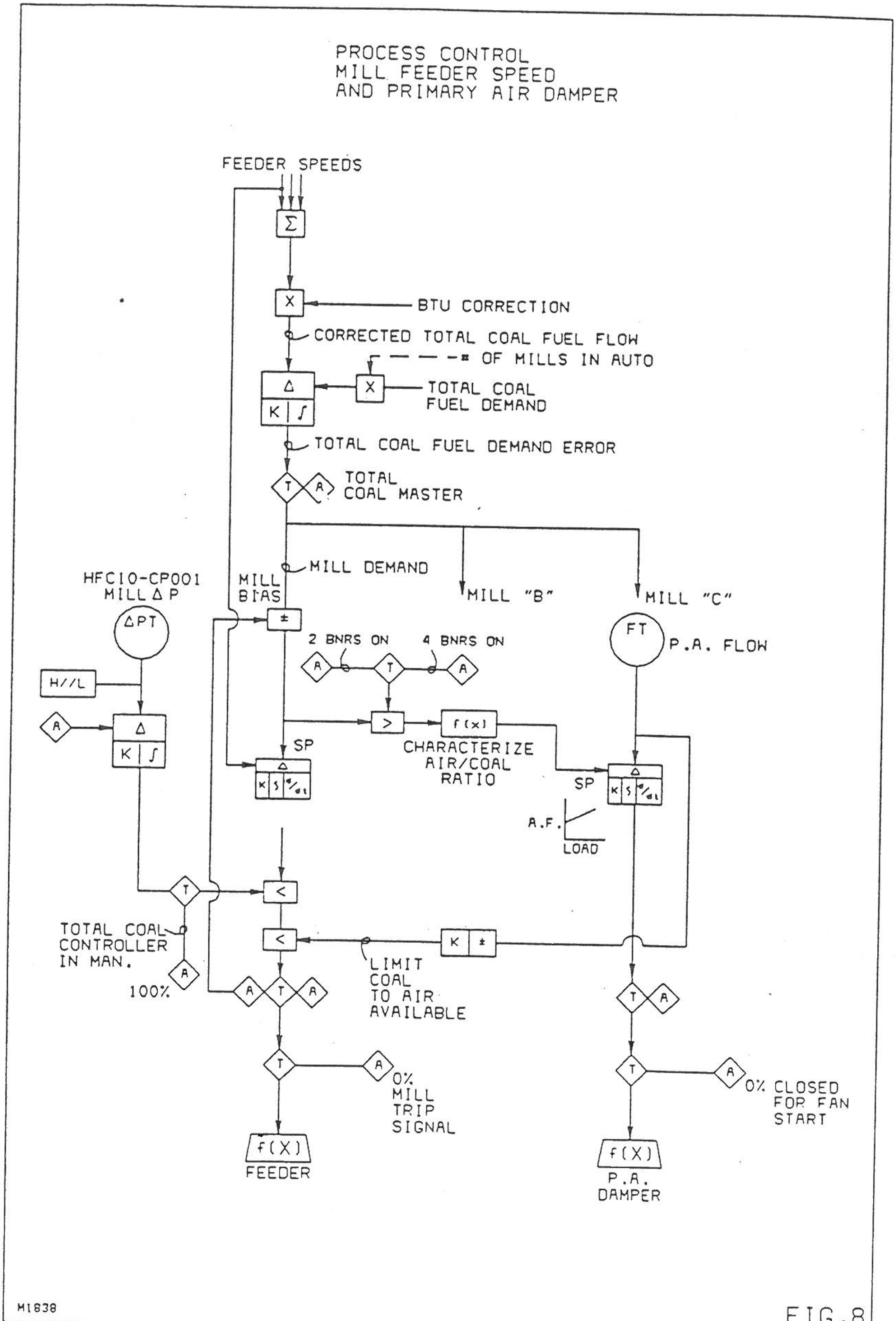
FIG. 6



MPS 170
PULVERIZER AIR/COAL
CHARACTERIZATION
OMAHA PPD
NO. OMAHA STA. #5
COAL PIPE VELOCITY - FPS
AIR FLOW - M #/HR
% AIR FLOW
1.2 X 10^6 #/HR STEAM FLOW (3 MILLS)
A/C
90 81 72 63
109 98 87 76
100 90 80 70
3.5 3.0 2.5 2.0 1.6
0 10 20 30 40 50 60 70 80 90 100
% MILL MCR COAL FLOW
23 27 41 54 68
MILL COAL FLOW - M #/HR

M1843

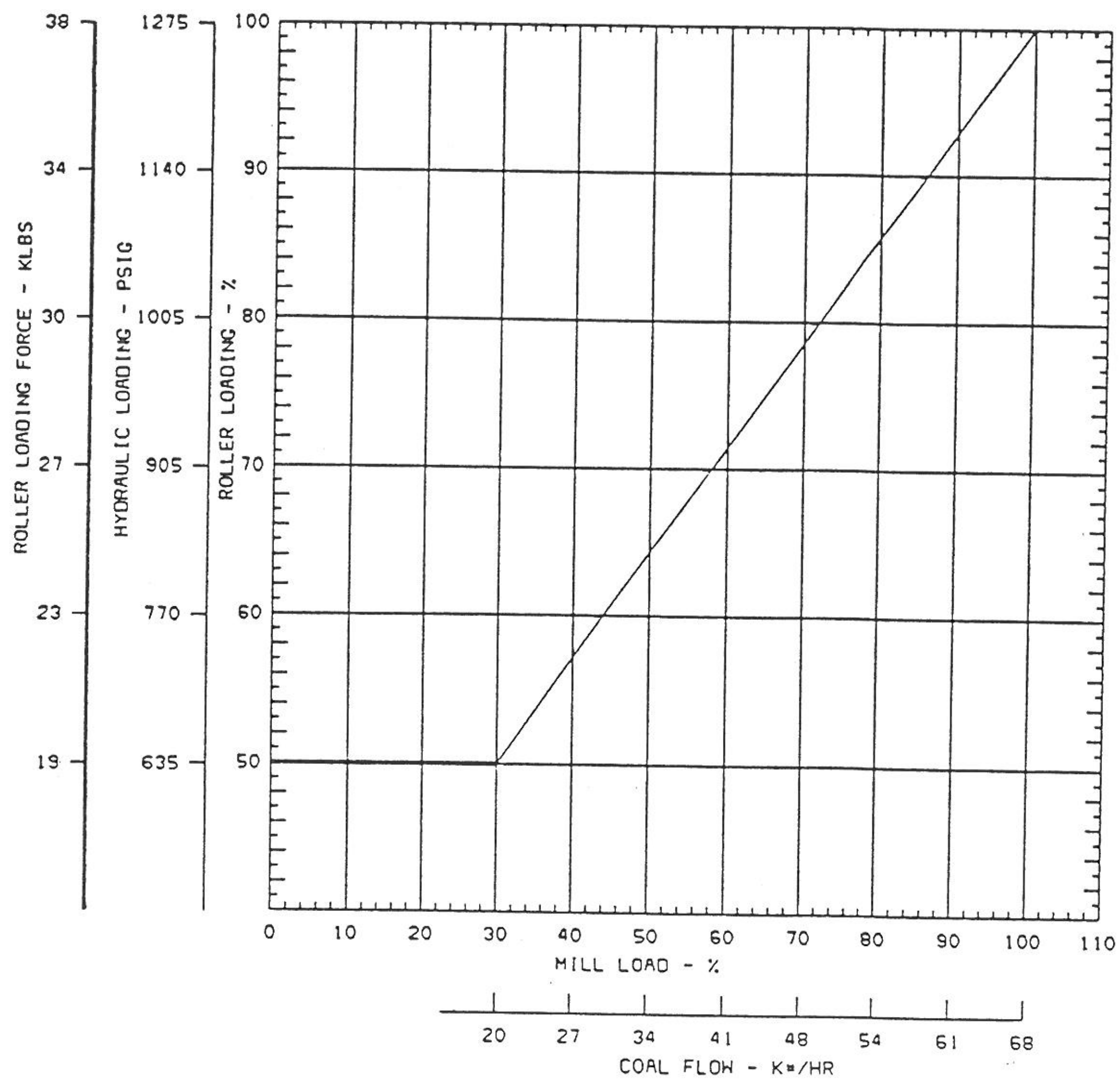
FIG. 7



PROCESS CONTROL
MILL FEEDER SPEED
AND PRIMARY AIR DAMPER
FEEDER SPEEDS
Σ
X
BTU CORRECTION
CORRECTED TOTAL COAL FUEL FLOW
OF MILLS IN AUTO
Δ
K | ∫
X
TOTAL COAL
FUEL DEMAND
TOTAL COAL FUEL DEMAND ERROR
T
A
TOTAL
COAL MASTER
MILL DEMAND
MILL "B"
MILL "C"
HFC10-CP001
MILL Δ P
ΔPT
MILL
BIAS
±
2 BNRS ON
4 BNRS ON
FT
P.A. FLOW
H//L
>
f(x)
CHARACTERIZE
AIR/COAL
RATIO
SP
A.F.
LOAD
<
K ±
TOTAL COAL
CONTROLLER
IN MAN.
100%
LIMIT
COAL
TO AIR
AVAILABLE
0%
MILL
TRIP
SIGNAL
0% CLOSED
FOR FAN
START
f(X)
FEEDER
P.A.
DAMPER
M1838

FIG.8

MPS 170
GRINDING ROLLER LOADING
VS
MILL LOAD CHARACTERIZATION
OMAHA PPD
NO. OMAHA STA. #5



M1841

FIG. 9

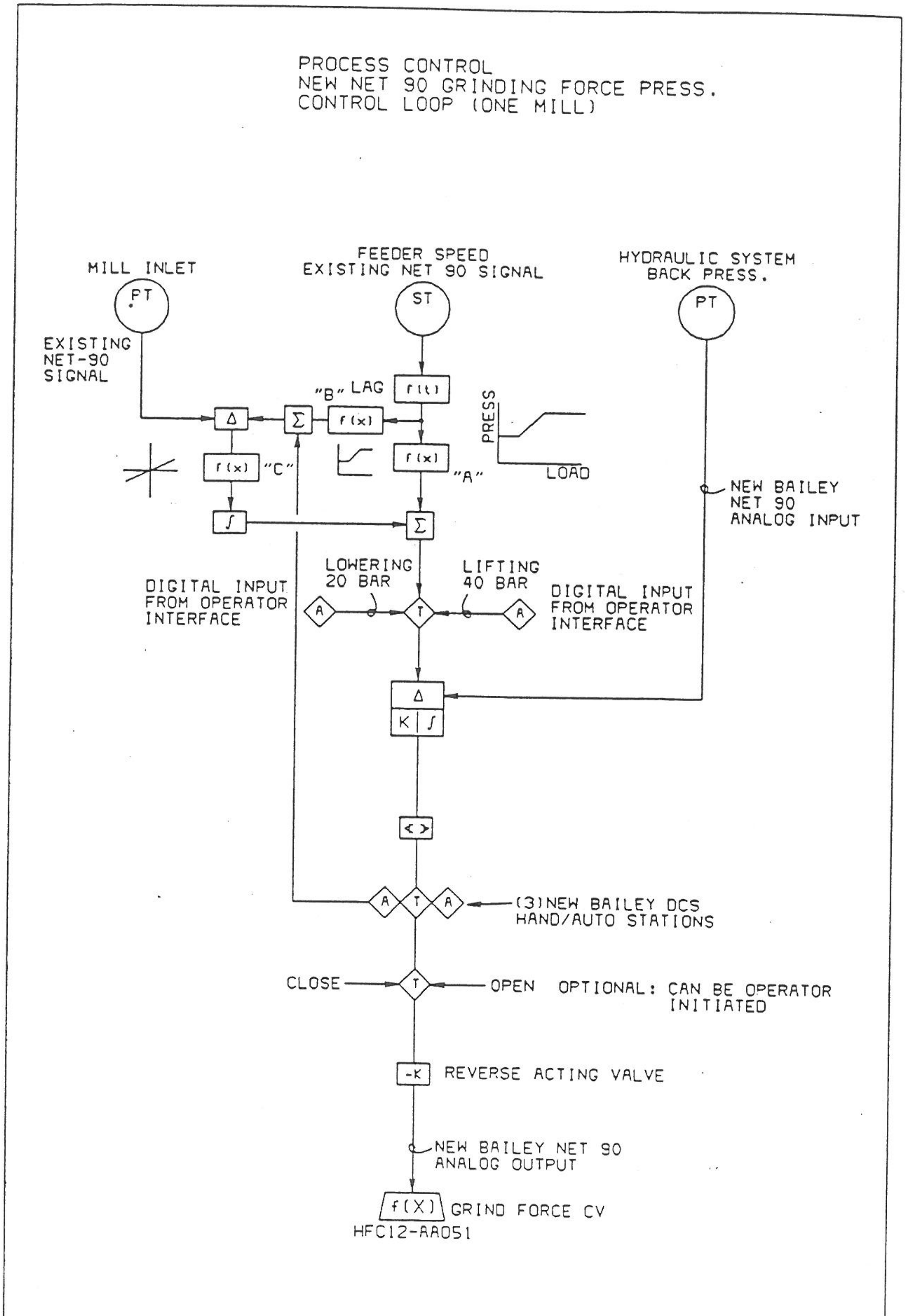
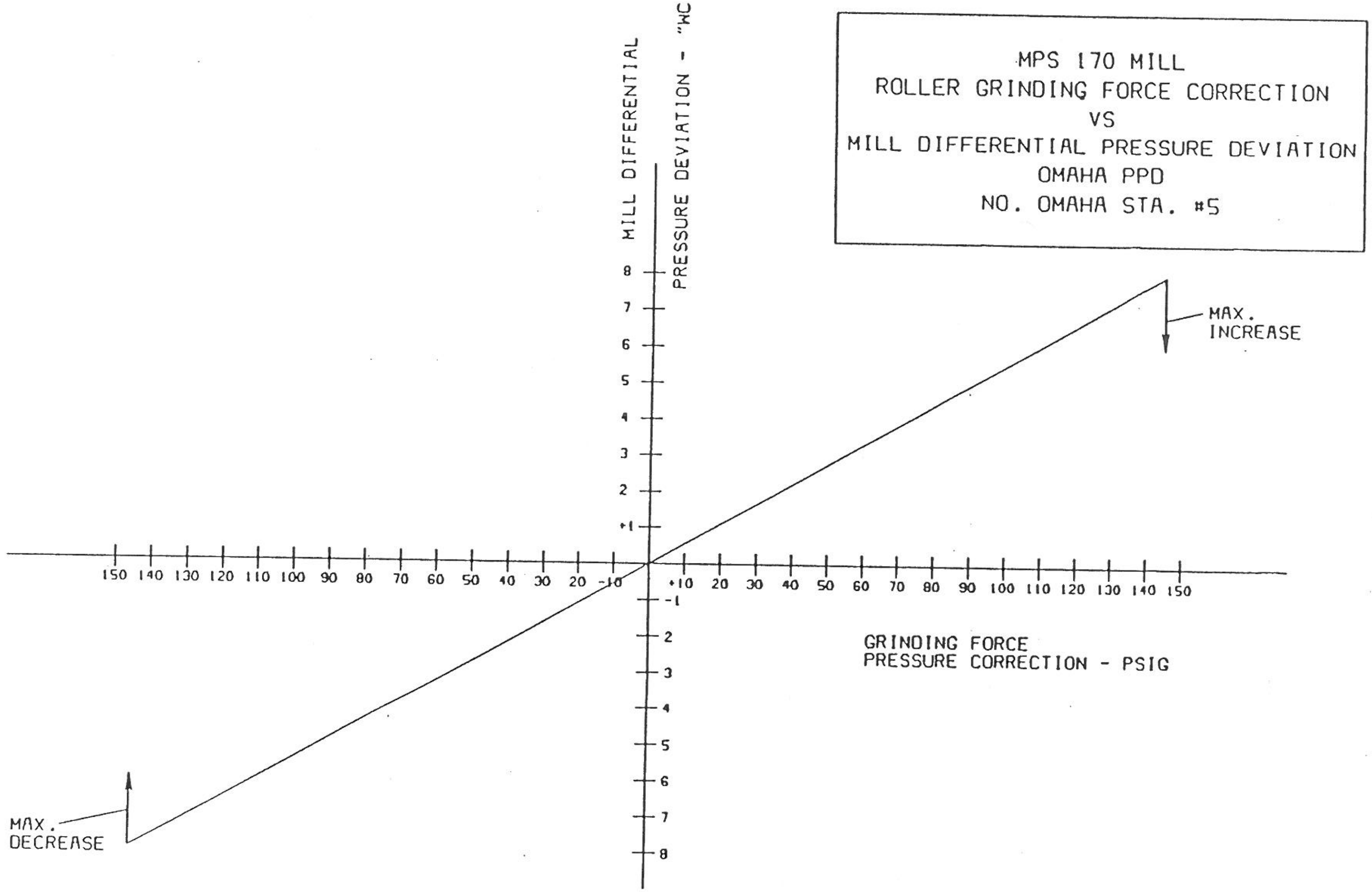

PROCESS CONTROL
NEW NET 90 GRINDING FORCE PRESS.
CONTROL LOOP (ONE MILL)
MILL INLET
PT
EXISTING NET-90 SIGNAL
FEEDER SPEED
EXISTING NET 90 SIGNAL
ST
HYDRAULIC SYSTEM BACK PRESS.
PT
"B" LAG
f(t)
f(x)
PRESS
LOAD
f(x) "C"
f(x) "A"
NEW BAILEY NET 90 ANALOG INPUT
LOWERING 20 BAR
LIFTING 40 BAR
DIGITAL INPUT FROM OPERATOR INTERFACE
A
T
A
DIGITAL INPUT FROM OPERATOR INTERFACE
K
(3)NEW BAILEY DCS HAND/AUTO STATIONS
CLOSE
OPEN
OPTIONAL: CAN BE OPERATOR INITIATED
-K
REVERSE ACTING VALVE
NEW BAILEY NET 90 ANALOG OUTPUT
f(X)
GRIND FORCE CV
HFC12-AA051
M1839

FIG. 10

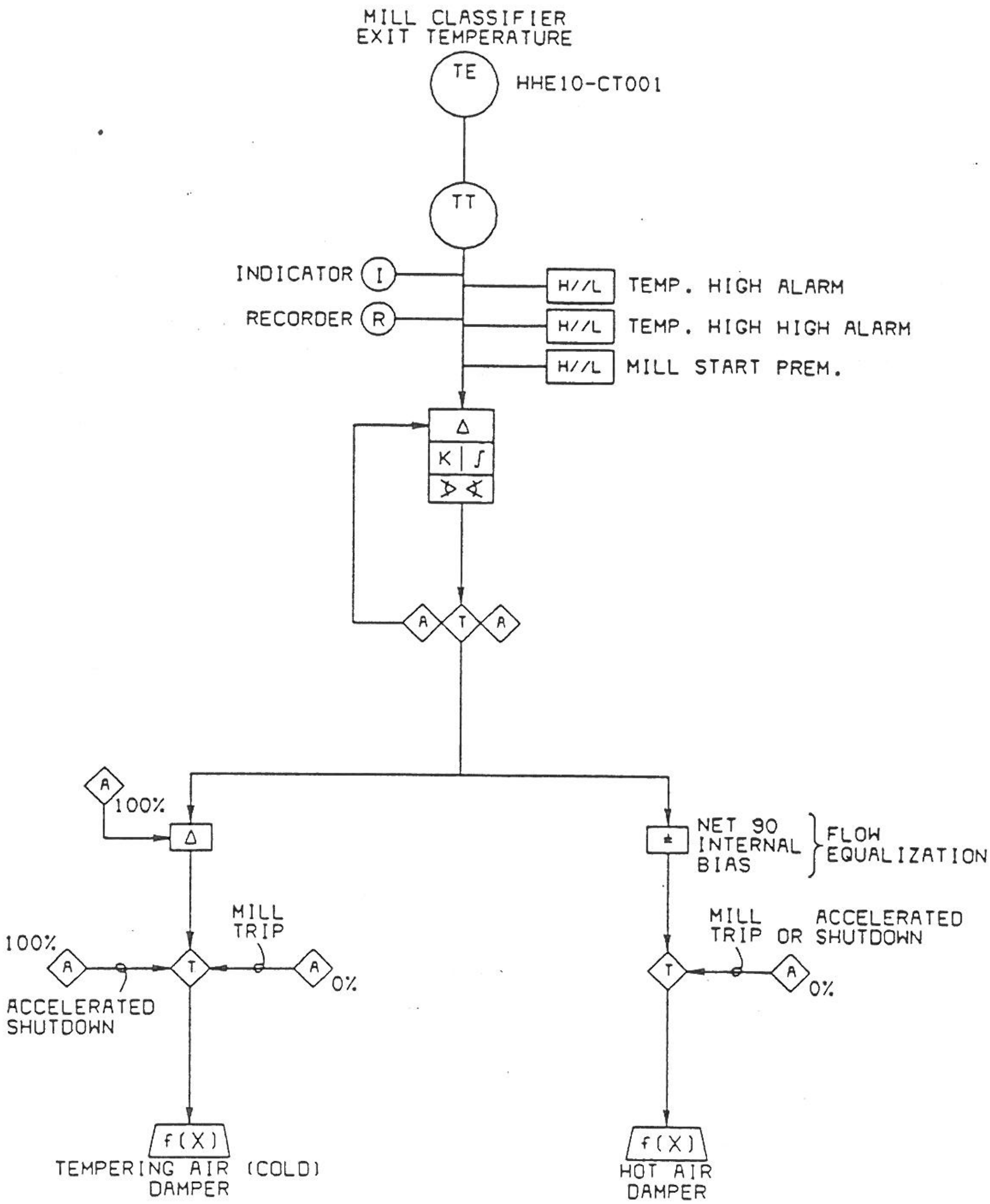


MPS 170 MILL
ROLLER GRINDING FORCE CORRECTION
VS
MILL DIFFERENTIAL PRESSURE DEVIATION
OMAHA PPD
NO. OMAHA STA. #5
MILL DIFFERENTIAL
PRESSURE DEVIATION - "WC
GRINDING FORCE
PRESSURE CORRECTION - PSIG
MAX.
INCREASE
MAX.
DECREASE

M1840

FIG. 11

PROCESS CONTROL
TEMPERING (COLD) AND HOT
AIR DAMPER CONTROL



M1837

FIG. 12

MPS 170 PULVERIZER
OPPD
NO. OMAHA STATION
FINENESS SUMMARY

ITEM	SPECIFIED VALUES	TEST VALUES (1)
Coal Throughput - #/Hr	63,000	63,000
Product Fineness:		
% thru 50 Mesh	98	99.2 - 99.9(2)
% thru 100 Mesh	-	92.5 - 95.2
% thru 200 Mesh	75	80.5 - 85.5
Coal Source	Powder River Basin	Powder River Basin
Coal Vein	Rawhide	Rawhide
Coal Moisture - %	30.59	29.6 - 31.8
Coal Grindability - Hg	63	53 - 58

(1) Tests Conducted June 12, 13, 21, 1991

(2) Range of Values for Three Mills;
50% Classifier Vane Position

FIG. 13

M1834

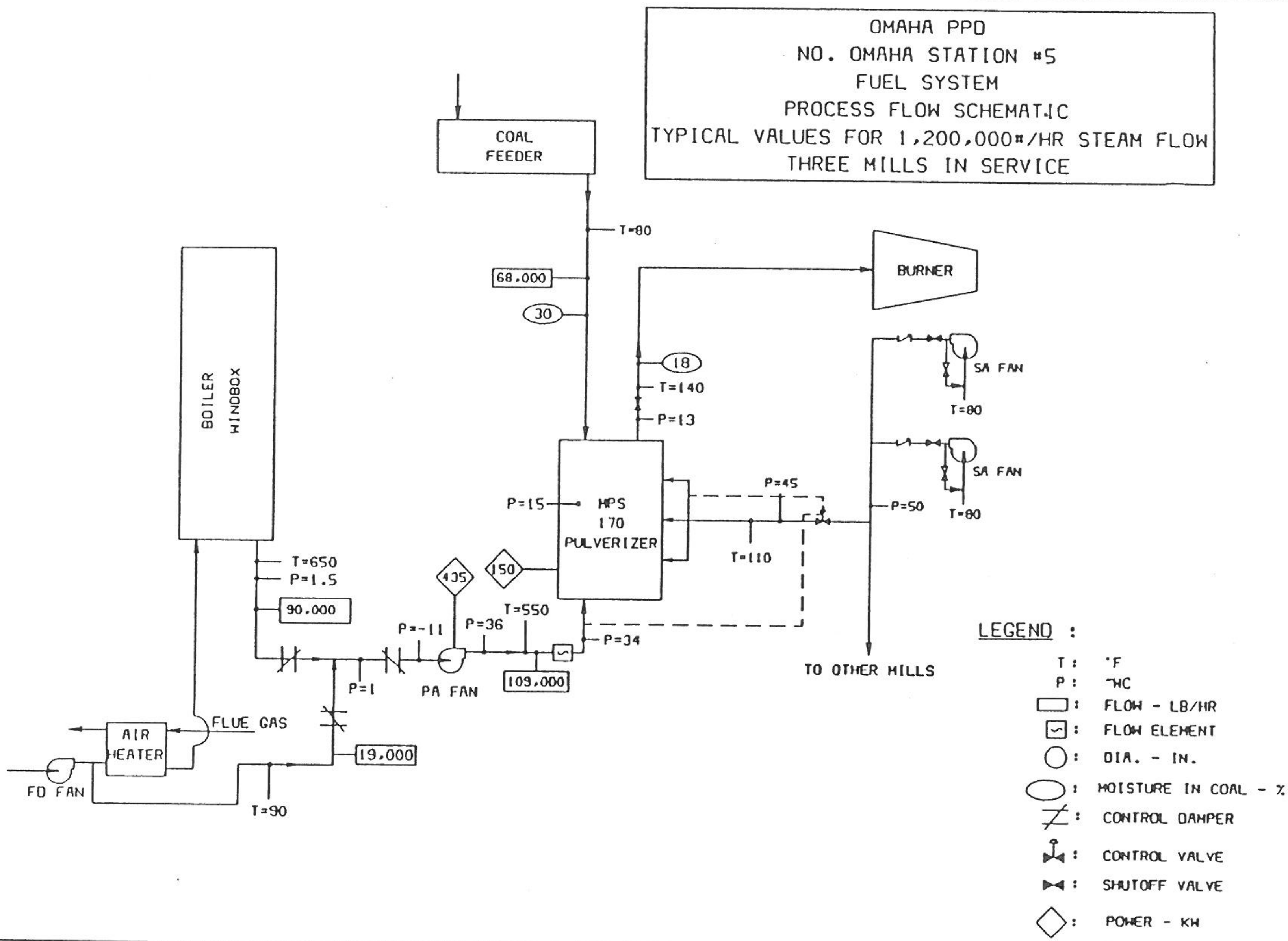

OMAHA PPD
NO. OMAHA STATION #5
FUEL SYSTEM
PROCESS FLOW SCHEMATIC
TYPICAL VALUES FOR 1,200,000#/HR STEAM FLOW
THREE MILLS IN SERVICE
COAL FEEDER
T=80
68,000
30
BURNER
18
T=140
P=13
SA FAN
T=80
SA FAN
T=80
P=50
P=45
T=110
MPS 170 PULVERIZER
P=15
150
435
P=34
TO OTHER MILLS
BOILER WINDBOX
T=650
P=1.5
90,000
P=-11
P=36
T=550
109,000
P=1
PA FAN
FLUE GAS
AIR HEATER
19,000
FD FAN
T=90
LEGEND :
T : °F
P : "WC
FLOW - LB/HR
FLOW ELEMENT
DIA. - IN.
MOISTURE IN COAL - %
CONTROL DAMPER
CONTROL VALVE
SHUTOFF VALVE
POWER - KW

FIG. 14

OMAHA PPD

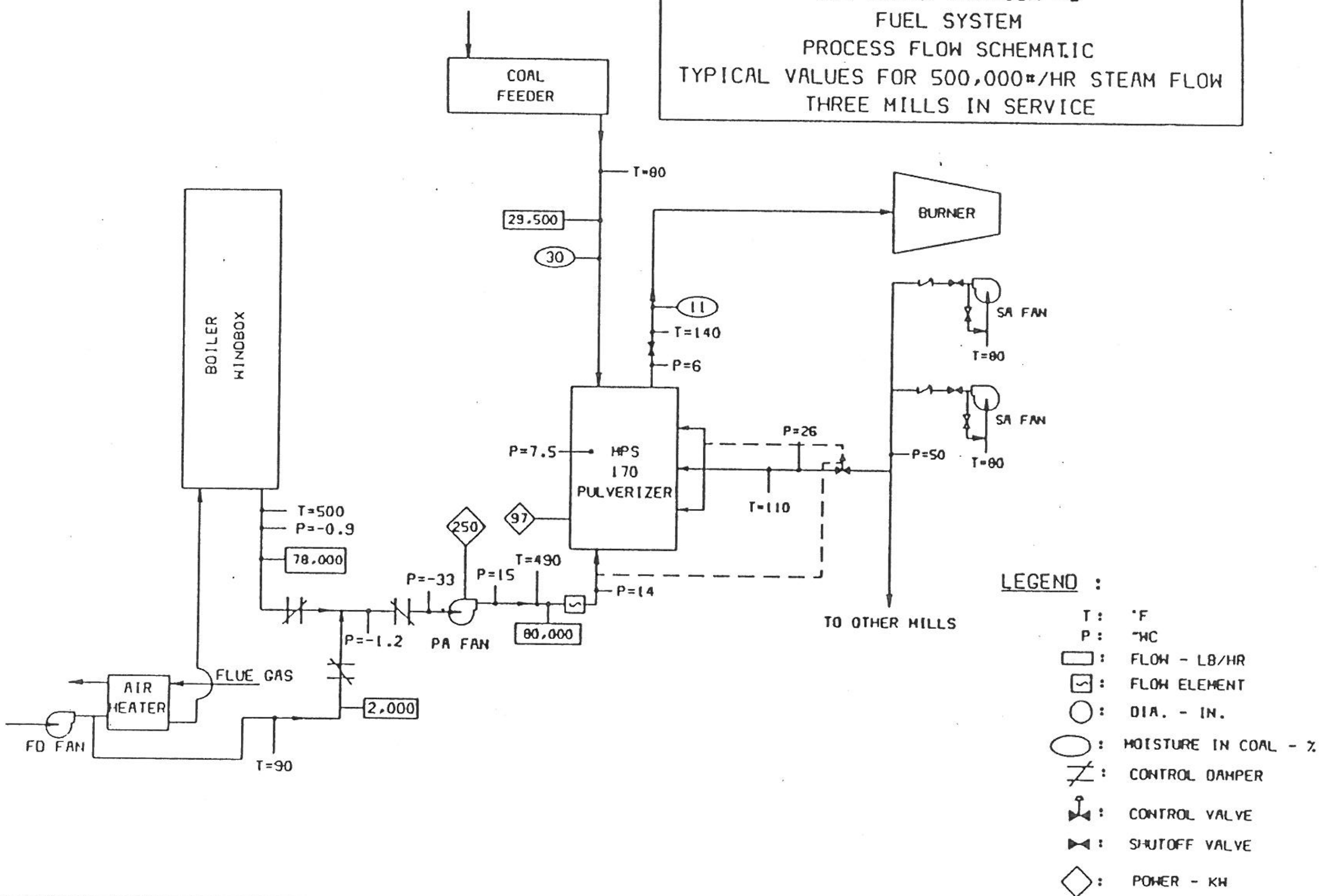
NO. OMAHA STATION #5

FUEL SYSTEM

PROCESS FLOW SCHEMATIC

TYPICAL VALUES FOR 500,000#/HR STEAM FLOW

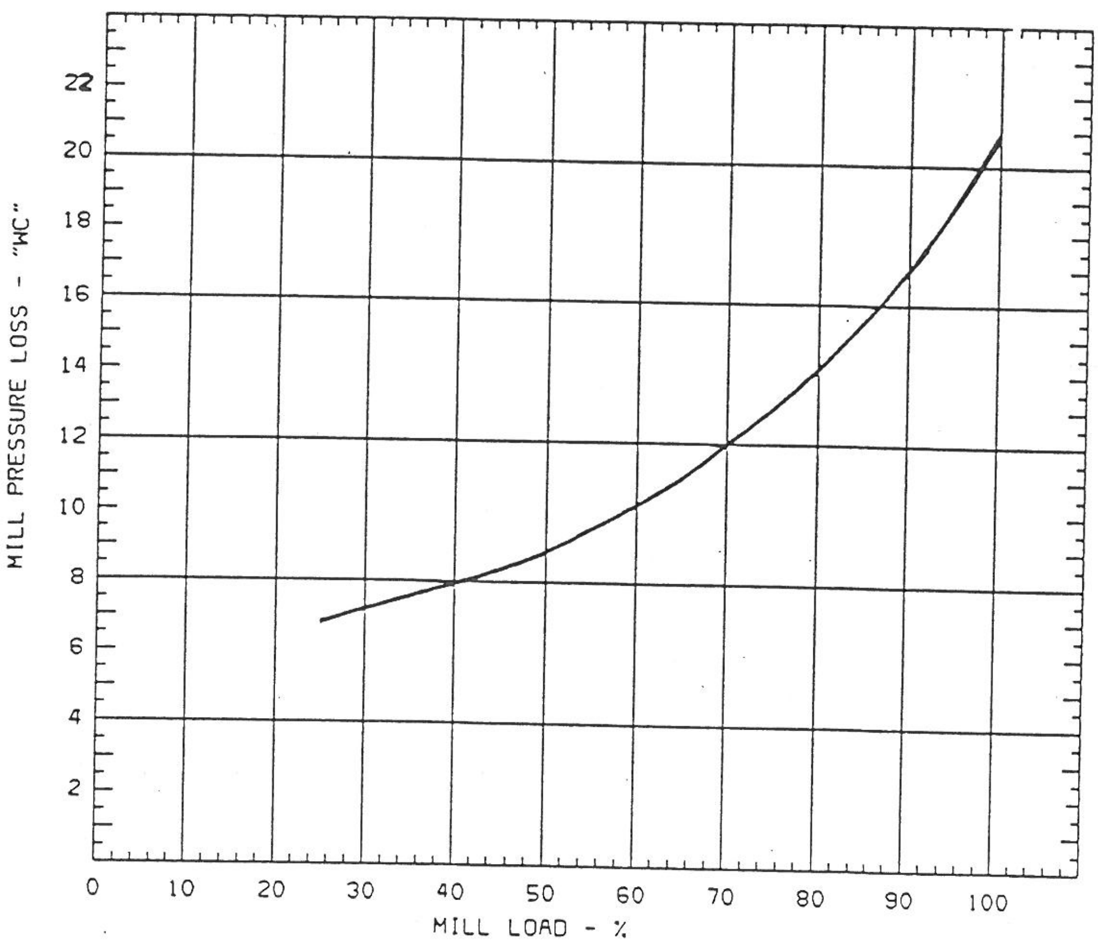
THREE MILLS IN SERVICE



M1835

FIG. 15

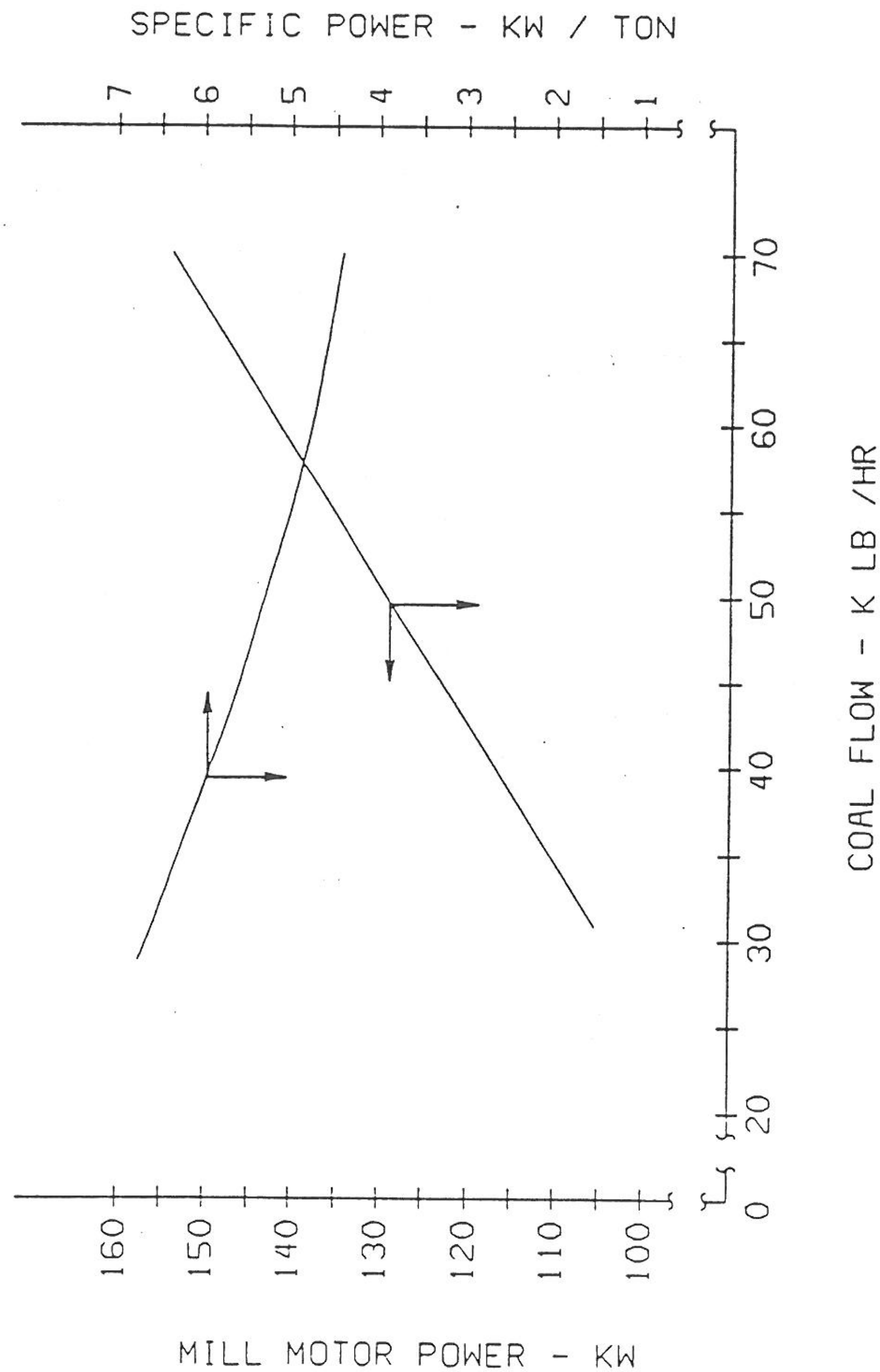
MPS 170 PULVERIZER
MILL PRESSURE LOSS
VS
MILL LOAD
OMAHA PPD
NO. OMAHA STA. #5



M1844

FIG. 16

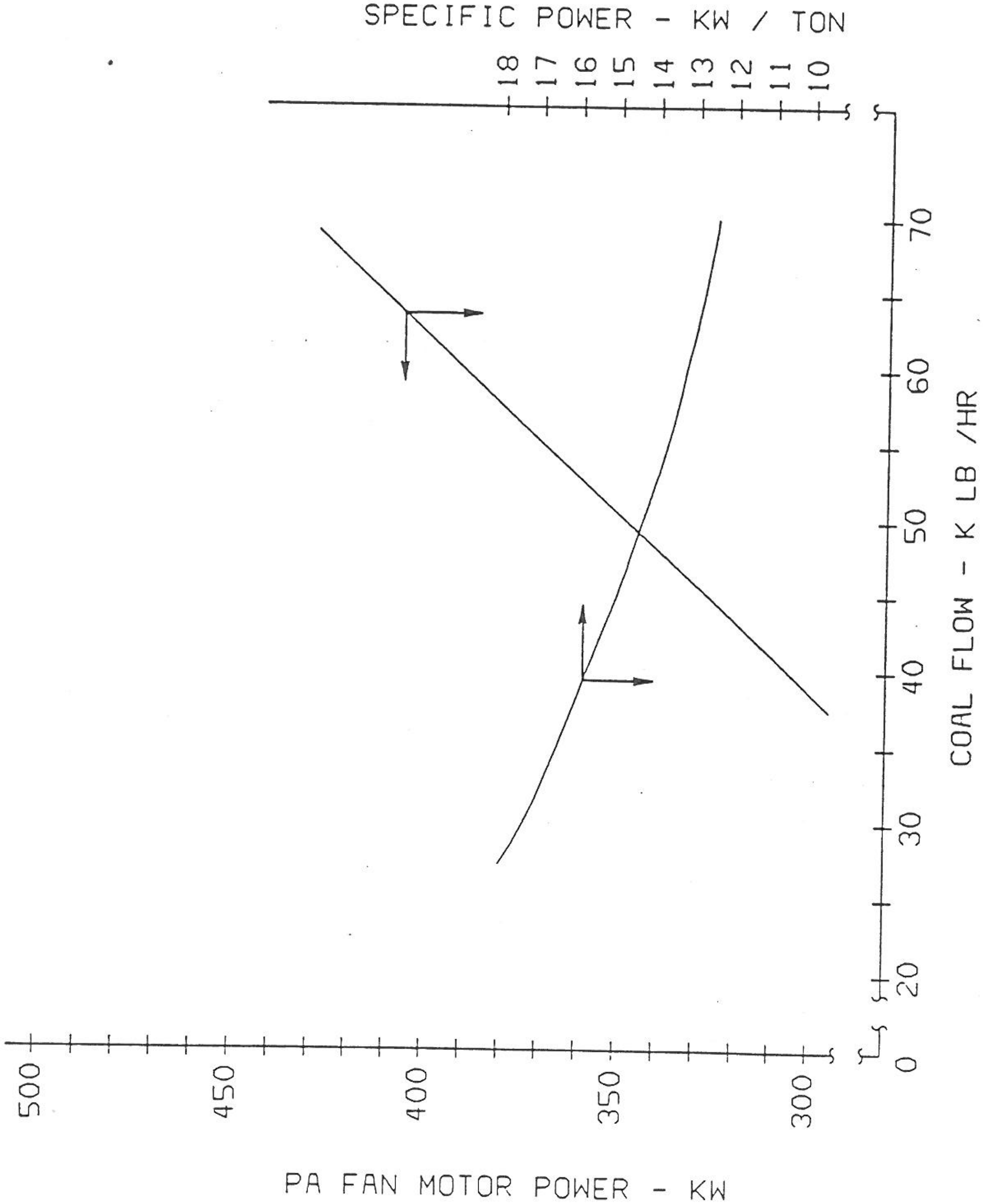
MPS 170 PULVERIZER
OPPD
NO. OMAHA STATION
MILL MOTOR POWER CONSUMPTION



M1845

FIG. 17

MPS 170 PULVERIZER
OPPD
NO. OMAHA STATION
PA FAN MOTOR POWER CONSUMPTION



M1846

FIG. 18

MPS 170 PULVERIZER
OPPD
NO. OMAHA STATION
TOTAL MILL & PA FAN MOTOR
POWER CONSUMPTION

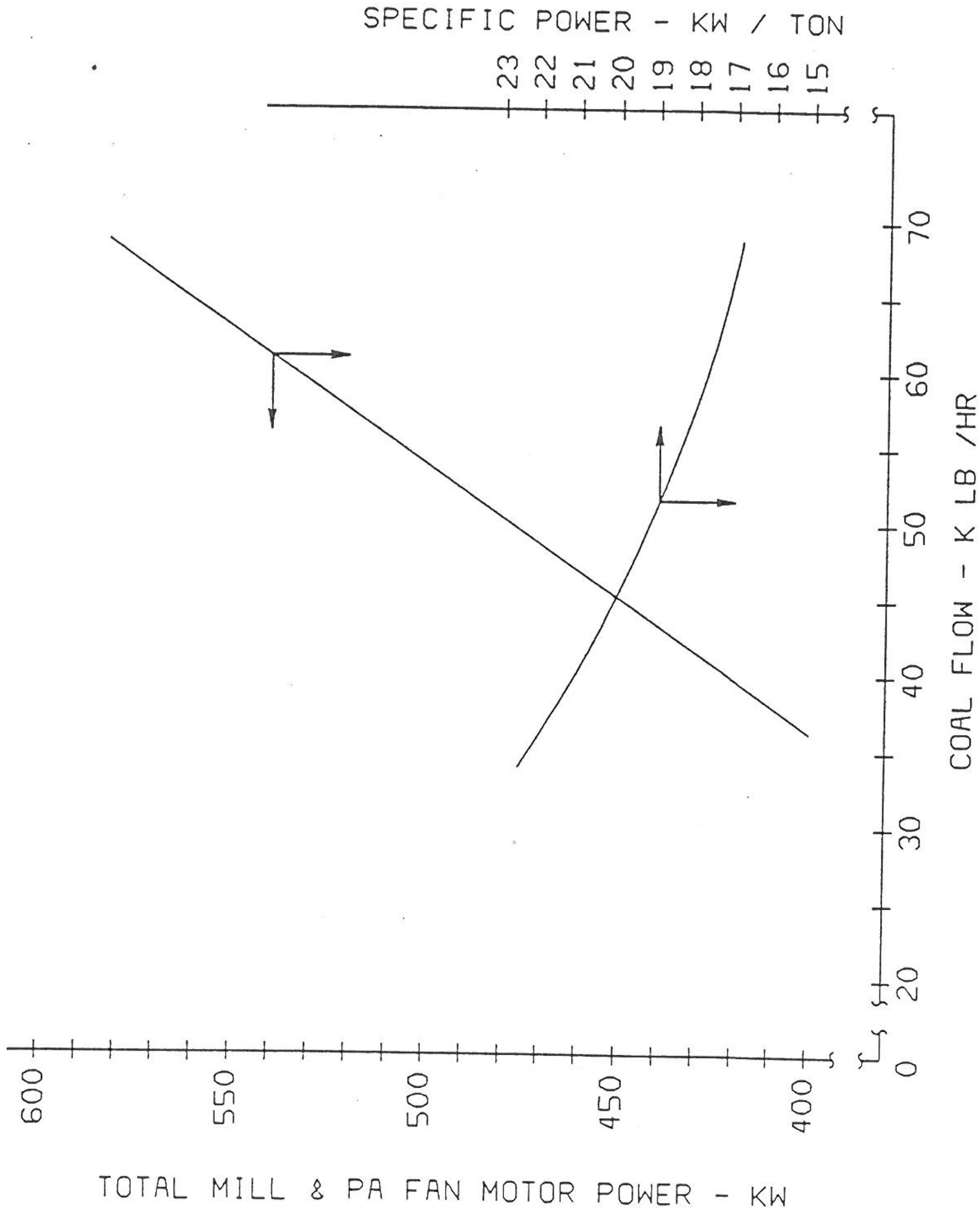
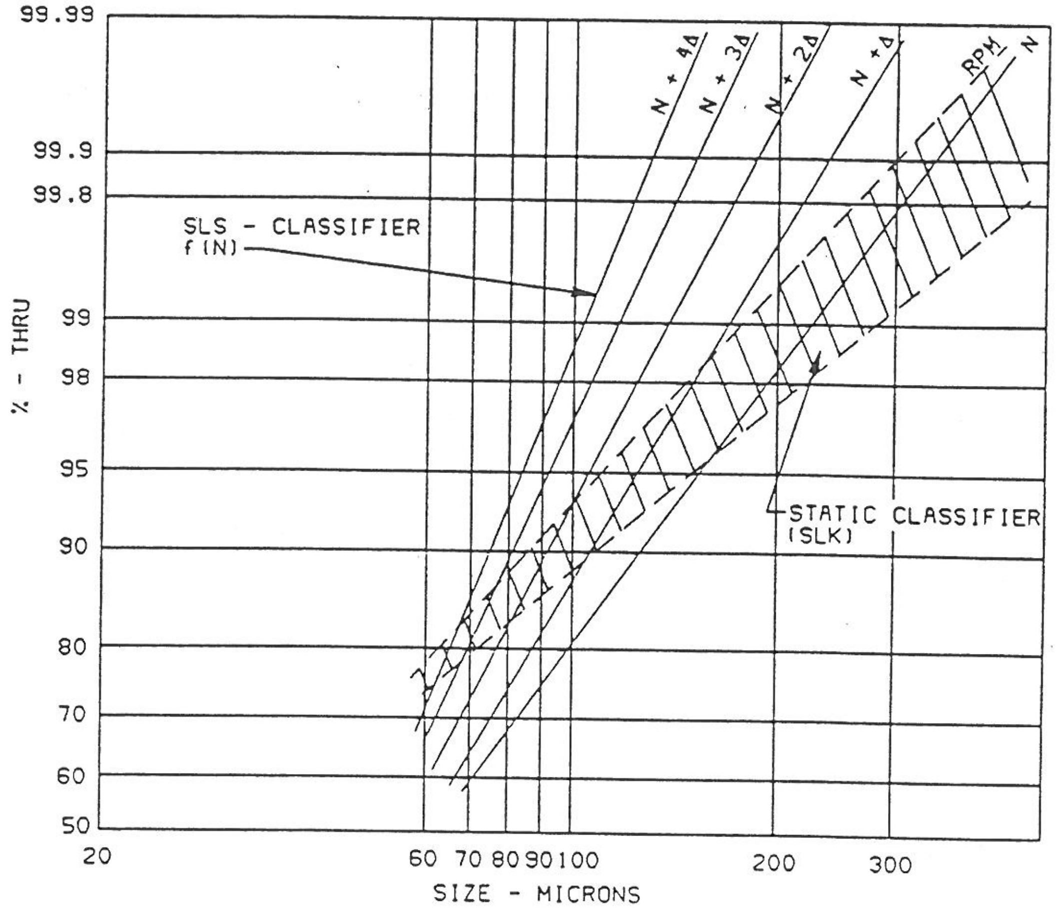


FIG. 19

PRODUCT FINENESS COMPARISON
SLS VS. SLK CLASSIFIER



M1848

FIG. 20