ACTON MASS FLOW SYSTEM APPLIED TO PFBC FEED

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ABSTRACT

Dense phase pneumatic conveying and the Acton Mass Flow concept are defined with emphasis on the specific advantages to the coal and dolomite feed to the Pressurized Fluidized Bed Combustor. The transport and feed functions are explored with a comparison of designing the process for a combined function or for individual functions. The equipment required to accomplish these functions is described together with a typical example of sizing and air or gas requirements. A general outline of the control system required to obtain a uniform feed rate is provided. The condition of the coal and dolomite and conveying gas as required to obtain reliable transport and feed will be discussed.

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ACTON SPECIALIZES IN THE PNEUMATIC TRANSPORT OF DRY MATERIALS. THESE CAN RANGE IN BULK DENSITY FROM 5#/CF TO 250#/CF AND IN PARTICLE SIZE FROM SUB-MICRON TO 3/8".

WE DO SOME WORK IN "DILUTE" PHASE" PNEUMATIC CONVEYING WHERE MATERIAL IS MOVED BY VELOCITY AND PRODUCT TO AIR LOADINGS ARE BELOW A 10:1 RATIO BY WEIGHT.

OUR PRIMARY EFFORTS ARE WITH "DENSE PHASE" SYSTEMS, WHICH CAN OBTAIN LOADINGS RANGING UP TO 100:1.

MOST DENSE PHASE SYSTEMS ARE BEST SUITED TO HANDLING POWDERS. THE ACTON MASS FLOW SYSTEM, SINCE IT DOES NOT DEPEND UPON "FLUIDIZATION" OF THE MATERIAL BEING TRANSPORTED, IS CAPABLE OF HANDLING MATERIALS TO 3/8" GRANULE SIZE.

PNEUMATIC CONVEYING GENERALLY USES GAS VELOCITY TO CONVEY THE MATERIAL, HAVING TO REACH PICK UP VELOCITIES, AND MAINTAIN CARRYING VELOCITIES TO TRANSPORT MATERIAL. THEREFORE THE HEAVIER AND COARSER THE GRANULE, THE HIGHER THE VELOCITY AND CORRESPONDING GAS VOLUME REQUIREMENT.

IN CONTRAST THE ACTON MASS FLOW SYSTEM CREATES A DENSE, LOWLY AERATED MASS OF MATERIAL WHICH IS THEN MOVED THROUGH THE PIPELINE BY GAS PRESSURE. THIS REDUCES LINE VELOCITIES TO A RANGE OF 500 to 2000 FPM INSTEAD OF 3000 TO 8000 FPM WITH A CORRESPONDING REDUCTION IN GAS VOLUME.

THE ACTON MASS FLOW SYSTEM OFFERS SEVERAL FEATURES WHICH CAN BE ADVANTAGEOUS IN THE FEEDING OF A PFBC.

LOW VELOCITY MINIMIZES SYSTEM WEAR AND SUBSEQUENT MAINTENANCE.

LOW VOLUME INTRODUCES A MINIMUM OF GAS INTO THE COMBUSTION CHAMBER.

LOW VELOCITY MINIMIZES FINES GENERATION WHICH WILL BE REFLECTED IN THE EXHAUST GAS PARTICULATE CARRY-OVER.

MATERIAL TRANSPORT CAN BE VARIED BY SIMPLE GAS FLOW ADJUSTMENT.

MULTIPLE LINES CAN BE FED FROM A SINGLE GAS PRESSURE SOURCE (ACTON MASS FLOW PUMP).

CONTINUOUS FLOW CAN BE ACHIEVED BY LOCK-HOPPER FEED.

THE ACTON MASS FLOW SYSTEM IS NON-PLUGGING.

IN THE PFBC APPLICATION THE REQUIREMENT IS TO TRANSFER COAL AND DOLOMITE FROM A STORAGE AREA TO THE COMBUSTOR AND TO CHARGE THE COMBUSTOR AT A CONTROLLED RATE. THESE FUNCTIONS MAY BE APPROACHED AS A COMBINED OPERATION OR AS SEPARATE OPERATIONS. I RECOMMEND DESIGNING FOR TWO (2) SEPARATE FUNCTIONS, THAT IS, HAVING A TRANSPORT SYSTEM AND A FEED SYSTEM.

THE FEED SYSTEM PUMP WOULD BE SET AS CLOSE TO THE COMBUSTOR AS POSSIBLE THUS ISOLATING THE FEED FROM SHORT TERM VARIATIONS THAT MAY OCCUR IN A LONG LINE.

THE ACTON APPROACH TO LONG DISTANCE TRANSPORT IS TO CAUSE THE MATERIAL TO FORM A DENSE MASS IN THE LINE. PRESSURE IS THEN BUILT UP BEHIND THIS MASS AND THIS PRESSURE DRIVES THE MASS THROUGH THE LINE. THE RESULTING MASS FLOW CAN BE SEEN BY RUNNING A PRESSURE PROFILE OF THE LINE.

A PRESSURE SENSOR WILL REGISTER DURING PASSAGE OF A PRESSURE-PISTON AND WILL BE BLANKED OFF AS A MATERIAL MASS PASSES. A SIGNAL FROM THE SENSOR, THROUGH AN AMPLIFIER TO A STRIP CHART RECORDER, WILL PRODUCE A MODIFIED SINE WAVE. SEE FIGURE 1.

THIS CHART WILL SHOW THE FREQUENCY OF THE MASS FORMATION.

THIS FREQUENCY WILL VARY WITH DIFFERENT MATERIALS, BUT IS USUALLY IN THE 3 to 5 SECOND RANGE. FROM THIS DATA AND THE MATERIAL DENSITY AND AVERAGE TRANSFER RATE, WE CAN CALCULATE THE SIZE OF THE MATERIAL MASS. THIS WILL RANGE FROM 6 TO 8 FEET FOR MATERIALS SUCH AS OUR COAL AND DOLOMITE. THE PRESSURE PISTON WILL OCCUPY ABOUT 8 TO 12 FOOT OF SPACE.

WE HAVE AN IN-HOUSE TEST FACILITY FITTED WITH ACRYLIC PIPE SECTIONS WHICH PERMITS OBSERVATION OF THIS FLOW PHENOMENA. THE OBSERVATIONS VERIFY THE PRESSURE SENSOR DATA.

THIS CONCEPT AVOIDS DENSE PHASE CONVEYING'S RELIANCE ON AERATION AND THE STRONG PLUGGING TENDENCIES THAT PLACED LIMITS ON ITS ABILITY TO TRANSPORT OVER AN EXTENDED DISTANCE. WITH THE ACTON SYSTEM DISTANCE IS LIMITED ONLY BY THE AVAILABLE PRESSURE.

WITH THIS APPROACH THE PREPARATION AND STORAGE FACILITY CAN BE KEPT AT THE RECEIVING-UNLOADING LOCATION. THE MATERIALS CAN BE TRANSPORTED TO THE COMBUSTOR LOCATION ON A BATCH BASIS AT A RATE COMPATABLE WITH USAGE.

REFER TO FIGURE 2, PFBC TRANSPORT AND FEED SYSTEM FLOW DIAGRAM. THE SYSTEMS FOR COAL AND DOLOMITE ARE IDENTICAL IN CONCEPT AND OPERATION, DIFFERING IN SIZE BECAUSE OF THE USAGE REQUIREMENT. THE COAL SYSTEM WILL BE USED AS AN EXAMPLE. THE DESIGN CONCEPTS WILL ALSO APPLY TO THE DOLOMITE SYSTEM.

THE TRANSPORT SYSTEM CONSISTS OF AN ACTON MASS FLOW PUMP, THE TRANSFER LINE, AND A RECEIVER.

THE FEED SYSTEM CONSISTS OF A LOCK-HOPPER, AN ACTON MASS FLOW PUMP, AND MULTIPLE FEED LINES.

THE TRANSPORT RECEIVER AND FEED LOCK-HOPPER FUNCTIONS ARE PERFORMED BY ONE VESSEL.

IN DESIGNING THE FEED SYSTEM CERTAIN COMBUSTOR REQUIREMENTS, OTHER THAN PROVIDING A GIVEN FLOW OF MATERIAL, MUST BE CONSIDERED.

FIRST, TO OBTAIN MAXIMUM COMBUSTION EFFICIENCY THE FEED MUST BE UNIFORM.

THE MASS FLOW FREQUENCY OF 3 TO 5 SECONDS HAS BEEN DESCRIBED. THIS FREQUENCY MAY BE RAPID ENOUGH TO PROVIDE SATISFACTORY COMBUSTION. HOWEVER THE COMBUSTION MAY BE IMPROVED BY SMOOTHING OUT THESE FLUCTUATIONS.

IF THE FEED PUMP IS LOCATED CLOSE TO THE BASE OF THE COMBUSTOR THE SYSTEM IS REQUIRED MAINLY TO LIFT THE COAL TO THE BED OR BEDS. THIS CONFIGURATION PERMITS ABANDONING THE "MASS FLOW" AND OBTAINING A STEADY CONTINUOUS REGULATED DISCHARGE FROM THE LINE. ALSO, THE CONVEYING GAS FLOW REQUIRED IN A VERTICAL LINE IS LESS THAN HALF THAT REQUIRED IN A HORIZONTAL LINE FOR THE SAME RATE SO LESS CONVEYING GAS IS INTRODUCED INTO THE COMBUSTOR. THIS CHANGE IN FLOW CHARACTERISTIC IS THE MAIN REASON FOR SPLITTING THE TRANSPORT AND FEED FUNCTIONS.

THE FEED LINE SIZE IS DETERMINED BY THE MAXIMUM AND MINIMUM RATE REQUIRED TO BE DELIVERED TO THE COMBUSTOR.

THE MATERIAL FLOW FROM AN ACTON PUMP IS REGULATED BY VARYING THE GAS FLOW TO THE PUMP. WE HAVE BEEN ABLE TO OBTAIN AND MAINTAIN CONSTANT RATES OVER A 4:1 RANGE IN A GIVEN PIPE SIZE. WIDER TURNDOWN RATIOS WILL REQUIRE FURTHER DEVELOPMENT WORK AND POSSIBLY A DUAL FEED LINE ARRANGEMENT.

A DUAL LINE WOULD HAVE A CROSS-OVER RANGE. FOR EXAMPLE, IF THE REQUIRED FEED RANGE WAS FROM 5# TO 30# PER CHARGING POINT WE WOULD USE A 1" LINE FOR RATES OF FROM 5 TO 15#/MINUTE AND A 1-1/1" LINE FOR RATES FROM 10 TO 30#/MINUTE. SYSTEM CONTROL WOULD BE SIMPLIFIED IF THE TURNDOWN COULD BE HELD AT 7 TO 28#/MINUTE WHICH COULD BE HANDLED IN ONE (1) 1-1/2" LINE.

IN THE FEED SYSTEM DESCRIBED THE LOADING WOULD RUN 30:1 AND THE FEED PUMP WOULD BE OPERATING AT 50 PSIG ABOVE THE COMBUSTOR PRESSURE.

OUR PUMP SIZING IS NORMALLY BASED ON SUPPLYING THE REQUIRED RATE WITH A PUMP OPERATING AT 6 to 8 CYCLES PER HOUR. THE PFBC IS A NON-INTERRUPTABLE PROCESS, THEREFORE THERE SHOULD BE A TIME RESERVE BUILT INTO THE SYSTEM TO PERMIT ROUTINE MAINTENANCE OR CORRECTIONS UPSTREAM. THE TIME RESERVE SHOULD BE AS CLOSE AS POSSIBLE TO THE COMBUSTOR. THE SIZING OF THE FEED PUMP SHOULD SUPPLY THIS RESERVOIR. SELECTING THE FEED PUMP CAPACITY TO STORE ONE (1) HOUR'S USAGE SEEMS REASONABLE.

IF A FEED SYSTEM IS TO BE SIZED FOR A RATE OF 25 TPH THE FEED PUMP WOULD HAVE A MINIMUM CAPACITY OF 1000 CF. THIS SHOULD BE THE MINIMUM RESERVE AVAILABLE DURING NORMAL OPERATION. THE TOTAL FEED PUMP VOLUME WOULD BE 1500 CF. WHEN ITS LEVEL DROPS TO 1000 CF IT WOULD BE RE-CHARGED FROM A 500 CF LOCK-HOPPER. THIS RE-CHARGING WOULD OCCUR AT THIRTY (30) MINUTE INTERVALS.

FOR THE LOCK-HOPPER VALVING WE HAVE SELECTED A SPECIAL MODIFICATION OF THE GEMCO TYPE T SPHERICAL VALVE. THIS VALVE USES A HARD FACED SPHERICAL DISC MATING WITH A HARD FACED GROUND SPHERICAL SEAT TO PROVIDE TIGHT SHUT-OFF AT 200 PSIG WITH TEMPERATURES TO 600° F. THE VALVE BODY IS ECCENTRIC MOUNTED TO PROVIDE CLEARANCE DURING ROTATION AND ADJUSTMENT FOR TIGHT SEATING.

THE LOCK-HOPPER WOULD DISCHARGE TO THE FEED PUMP AND THEN BE RE-CHARGED BY THE TRANSPORT PUMP. TO INSURE A FULL CHARGE, 500 CF, AT THE LOCK-HOPPER FOR THE NEXT CYCLE THE TRANSPORT PUMP SHOULD RE-CHARGE THE LOCK-HOPPER IN TWENTY (20) MINUTES. THEREFORE THE DESIGN RATE FOR THE TRANSPORT SYSTEM BECOMES 1250#/MINUTE.

THE TRANSPORT PUMP CAPACITY COULD BE PICKED UP FROM 125 CF TO 500 CF, REQUIRING FROM 4 TO 1 CYCLE TO FILL THE LOCK-HOPPER. NORMALLY THE SIZE SELECTION IS A COST-TRADE OFF IN THE SYSTEM DESIGN. THE COST DIFFERENTIAL FROM A 125 TO 500 CF PUMP WILL NOT BE A SIGNIFICANT AMOUNT IN THIS OVERALL PROJECT SCOPE; THEREFORE THE 500 CF SIZE SHOULD BE SELECTED SINCE IT OPERATES WITH LESS CYCLING AND WILL PROVIDE BETTER LONG TERM OPERATION.

THE LOCK-HOPPER WILL BE VENTED TO ATMOSPHERIC PRESSURE BEFORE IT IS RE-CHARGED SO THE TRANSPORT SYSTEM WILL OPERATE FROM ATMOSPHERIC PRESSURE.

TO OBTAIN THE SELECTED 1250#/MINUTE RATE THE ACTON TRANSPORT SYSTEM WILL REQUIRE A GAS FLOW OF 700 SCFM. THE SYSTEM OPERATING PRESSURE WILL BE DETERMINED BY THE TRANSPORT DISTANCE AND THE CHANGES IN ELEVATION. GAS PRESSURE TO THE VESSEL SHOULD BE IN THE 100 TO 125 PSIG RANGE. THE OPERATING PRESSURE CAN BE ESTIMATED BY ALLOWING 40 PSIG FOR THE FIRST 200 FT. AND ADDING 5 PSIG FOR EACH ADDITIONAL 100 FT., ASSUMING LIFT IS LESS THAN 30 FEET.

PROVISION MUST BE MADE TO EXHAUST THE CONVEYING GAS FROM THE LOCK-HOPPER. THIS GAS MUST BE FILTERED BEFORE IT IS EITHER EXHAUSTED TO ATMOSHPERE OR RE-CYCLED.

THE LOGIC FOLLOWED IN SIZING VESSELS FORCED THIS DESCRIPTION TO FLOW FROM THE FEED SYSTEM TO THE TRANSPORT SYSTEM.

THE TRANSPORT SYSTEM HAS BEEN COMPLETELY DEFINED NOW AND THE SIZING EXPLAINED FOR A SELECTED 25 TPH FEED RATE.

TO SUMMARIZE, THE TRANSPORT SYSTEM REQUIRES AN ACTON MASS FLOW PUMP (500 CF CAPACITY) LOCATED DIRECTLY UNDER THE DISCHARGE OF THE PREPARED COAL HOPPERS, AN ACTON CONVEYING LINE (DUAL 5" PIPE) FROM THE PUMP TO THE LOCK-HOPPER, THE LOCK-HOPPER-RECEIVER (500 CF CAPACITY) AND AN EXHAUST MEANS INCLUDING A BAG TYPE VENT FILTER.

FOR THE FEED SYSTEM ONLY THE FEED PUMP HAS BEEN SELECTED ALONG WITH THE COMBINATION LOCK-HOPPER-RECEIVER.

THE FEED LINE OR LINES MUST BE SELECTED TO COMPLETE THE FEED SYSTEM DESCRIPTION.

COMBUSTOR DESIGN CONCEPTS INCLUDE SINGLE BED AND MULTIPLE BED DESIGNS. IN A SINGLE BED DESIGN ALL FEED LINES SHOULD EXTEND FROM ONE (1) FEED PUMP. IN A MULTIPLE BED DESIGN I WOULD RECOMMEND KEEPING EACH BED ISOLATED BY HAVING A FEED PUMP FOR EACH BED

THE TOTAL FEED REQUIRED BY A BED WOULD BE DISTRIBUTED EQUALLY BETWEEN THE SEVERAL LINES AND THE LINES SIZED AS ILLUSTRATED IN THE TURN-DOWN DISCUSSION.

THIS IS A GENERAL DISCUSSION WHICH LAYS OUT THE GUIDELINES FOR SYSTEM DESIGN. EACH APPLICATION MUST BE EXPLORED TO DETERMINE THE OPTIMUM DESIGN. LOCATION OF THE STORAGE AREA RELATIVE TO THE COMBUSTOR, COMBUSTOR DESIGN (SINGLE VERSUS MULTIPLE BEDS) COMBUSTOR SIZE ARE ALL FACTORS AFFECTING TRANSPORT-FEED SYSTEM DESIGN.

SHORT DISTANCE TRANSFER AND/OR LOW RATES MIGHT MAKE A COMBINED SYSTEM ATTRACTIVE. FIGURE 3 PRESENTS A FLOW DIAGRAM FOR THIS CONFIGURATION.

ANOTHER ARRANGEMENT, SEE FIGURE 4, WOULD COMBINE THE LOCK-HOPPER AND TRANSPORT PUMP AND VALVE THE TRANSPORT LINE TO PERMIT DIRECT TRANSPORT INTO THE FEED PUMP WHILE IT IS PRESSURIZED.

THESE VARIATIONS ARE SUGGESTED TO EMPHASIZE THE NEED TO CAREFULLY EXAMINE THE COMBUSTOR REQUIREMENTS AND FACILITY LAYOUT BEFORE SPECIFYING A TRANSFER-FEED SYSTEM.

THE DISCUSSION TO THIS POINT HAS BEEN CONFINED TO THE METHOD OF MOVING THE COAL AND DOLOMITE AND THE MECHANICAL AND PNEUMATIC EQUIPMENT REQUIRED. THE OTHER IMPORTANT ASPECT OF THIS APPLICATION IS THE RATE CONTROL.

IN THE SPLIT SYSTEM CONCEPT THE RATE CONTROL OF THE TRANSPORT SYSTEM IS SIMPLE. A FIXED AMOUNT OF GAS IS ADMITTED INTO THE ACTON PUMP AND LINE AND THE COAL TRANSFERS AT A CONSTANT RATE. DEVIATIONS FROM THIS RATE ARE NOT CRITICAL. TRANSPORT PUMP CYCLES CAN BE VOLUME CONTROLLED.

THE FEED SYSTEM PRESENTS AN ENTIRELY DIFFERENT PROBLEM. PROPER COMBUSTION CONTROL REQUIRES THAT THE BED BE FED AT A CONSTANT RATE WITHIN A NARROW TOLERANCE BAND AND THAT THIS RATE BE VARIABLE WITHIN THE TURN-DOWN RANGE.

THE ACTON SYSTEM IS ADAPTABLE TO THIS SERVICE SINCE WE CAN VARY THE RATE OF DISCHARGE OF THE ACTON PUMP BY CONTROLLING THE FLOW OF SUPPLY GAS.

THE CONTROL LOOP MUST SENSE THE QUANTITY (WEIGHT) OF MATERIAL FED IN A GIVEN TIME SPAN AND PROVIDE FEED BACK TO TRIM THE GAS FLOW TO HOLD THE RATE CONSTANT AT THE SET VALUE.

THE FEED PUMP WOULD BE MOUNTED ON LOAD CELL SYSTEM. THIS CAN BE EITHER HYDRAULIC OR ELECTRONIC. THE LOAD CELL OUTPUT IS FED INTO A RATE CONTROLLER WHICH LOOKS AT THE CELL OUT PUT AT A PRESET TIME INTERVAL, SAY 10 SECONDS, CALCULATES THE AMOUNT FED AND COMPARES THAT TO A PRESET SIGNAL. DEVIATIONS ARE COMPENSATED BY FEEDBACK TO OPERATE THE GAS FLOW CONTROL VALVE.

THE VARIATION IN AIR FLOW WILL TRIM THE COAL DISCHARGE RATE TO BRING THE LOOP INTO BALANCE WITHIN THE PRESCRIBED TURNDOWN RANGE.

WEIGHT AND RATE PRINT OUT AND READOUT CAN BE PROVIDED AS REQUIRED.

THE CONVEYING CAPABILITY OF THE SYSTEM IS AFFECTED BY THE BULK DENSITY, PARTICLE SIZE AND DISTRIBUTION, AND MOISTURE CONDITION OF THE COAL AND DOLOMITE.

THE BULK DENSITIES OF THESE MATERIALS, 45 TO 55#/CF FOR COAL AND 90#/CF FOR DOLOMITE ARE WITHIN THE NOMINAL RANGE OF THE ACTON SYSTEM.
THE PARTICLE SIZE OF MINUS 1/4" FOR COAL AND MINUS 1/8" FOR DOLOMITE ARE SAFELY BELOW THE ACTON UPPER LIMIT OF 3/8".

THERE SHOULD BE A LOWER LIMIT OR AT LEAST A QUANTITATIVE LOWER LIMIT APPLIED TO THE PARTICLE SIZE RANGE.

IF EXCESSIVE FINES ARE PRESENT, A SUBSTANTIAL PERCENTAGE SUCH AS 20% MINUS 325 MESH, THE NATURAL FLOWABILITY OF THE MATERIALS WILL BE RETARDED. MORE GAS WOULD BE REQUIRED IN THE PUMP TO PROMOTE FLOW AND MAINTAIN RATE. THIS CONDITION WOULD REQUIRE REFINING THE CONTROL SYSTEM TO ADJUST NOT JUST THE TOTAL FLOW, BUT ALSO TO ADJUST THE GAS FLOW SPLIT BETWEEN THE PUMP AND THE LINE. THIS COMPLICATION IS ELIMINATED IF A LOWER FINES LIMIT IS MAINTAINED

AGAIN BECAUSE OF ITS DETRIMENTAL AFFECT ON MATERIAL FLOWABILITY, THE MOISTURE CONTENT OF THE COAL AND DOLOMITE MUST BE KEPT TO A MINIMUM. PERHAPS IT WOULD BE MORE APPROPRIATE TO SAY IT SHOULD BE MAINTAINED AT A CONSTANT MINIMUM MOISTURE CONTENT. AS WITH VARYING FINES CONTENT, VARIATIONS IN MOISTURE CONTENT CAN DRIVE THE CONTROL LOOP WILD.

THE ACTON SYSTEM IS CAPABLE OF TRANSPORTING VERY "STICKY" LOW FLOWABILITY MATERIALS SUCH AS PREPARED FOUNDRY SANDS, CAKE MIXES, TITANIUM DIOXIDE AND MANY METALLIC OXIDES; HOWEVER THESE SYSTEMS ARE SET UP TO HANDLE THIS TYPE OF MATERIAL. THEY DO NOT SEE A VARIATION FROM FREE-FLOWING TO EXTREMELY SLUGGISH AS COULD HAPPEN IN THIS APPLICATION IF THESE VARIABLES ARE NOT CONTROLLED.

ALSO, IN MOST INDUSTRIAL INSTALLATIONS, SMALL VARIATIONS IN TRANSFER RATES ARE NOT CRITICAL. IN THIS APPLICATION WE MUST MAINTAIN A CONSTANT RATE.

COAL FROM OUTSIDE STORAGE OR HAULING MUST HAVE THE SURFACE MOISTURE REMOVED PRIOR TO ENTERING THE TRANSPORT-FEED SYSTEM. THIS CAN BE ACCOMPLISHED IN AN AIR SUSPENSION TYPE DRIER. WE WOULD RECOMMEND CONSIDERING OUR ENTON DRYER WHICH PRESENTS AN ECONOMICAL AND EFFICIENT MEANS OF REMOVING MOISTURE.

THE ACTON MASS FLOW SYSTEM CAN PROVIDE A RELIABLE, LOW MAINTENANCE, LOW POWER CONSUMPTION MEANS OF OBTAINING A CONTROLLED FEED RATE TO THE PFBC. ITS OPERATION CAN BE OPTIMIZED BY USING A PAIR OF SYSTEMS IN SERIES; ONE TO TRANSPORT THE MATERIAL AND ONE TO FEED IT TO THE COMBUSTOR BY CONTROLLING THE FINES CONTENT OF THE FEED TO 10% AND BY REMOVING SURFACE MOISTURE FROM THE FEED.

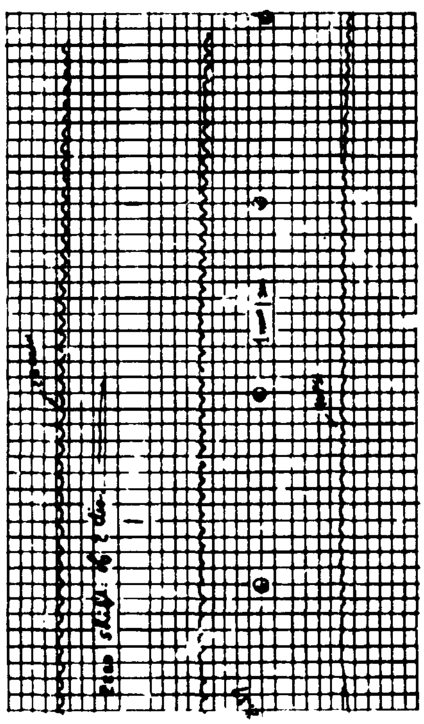

FIG. 1 PRESSURE TRACE

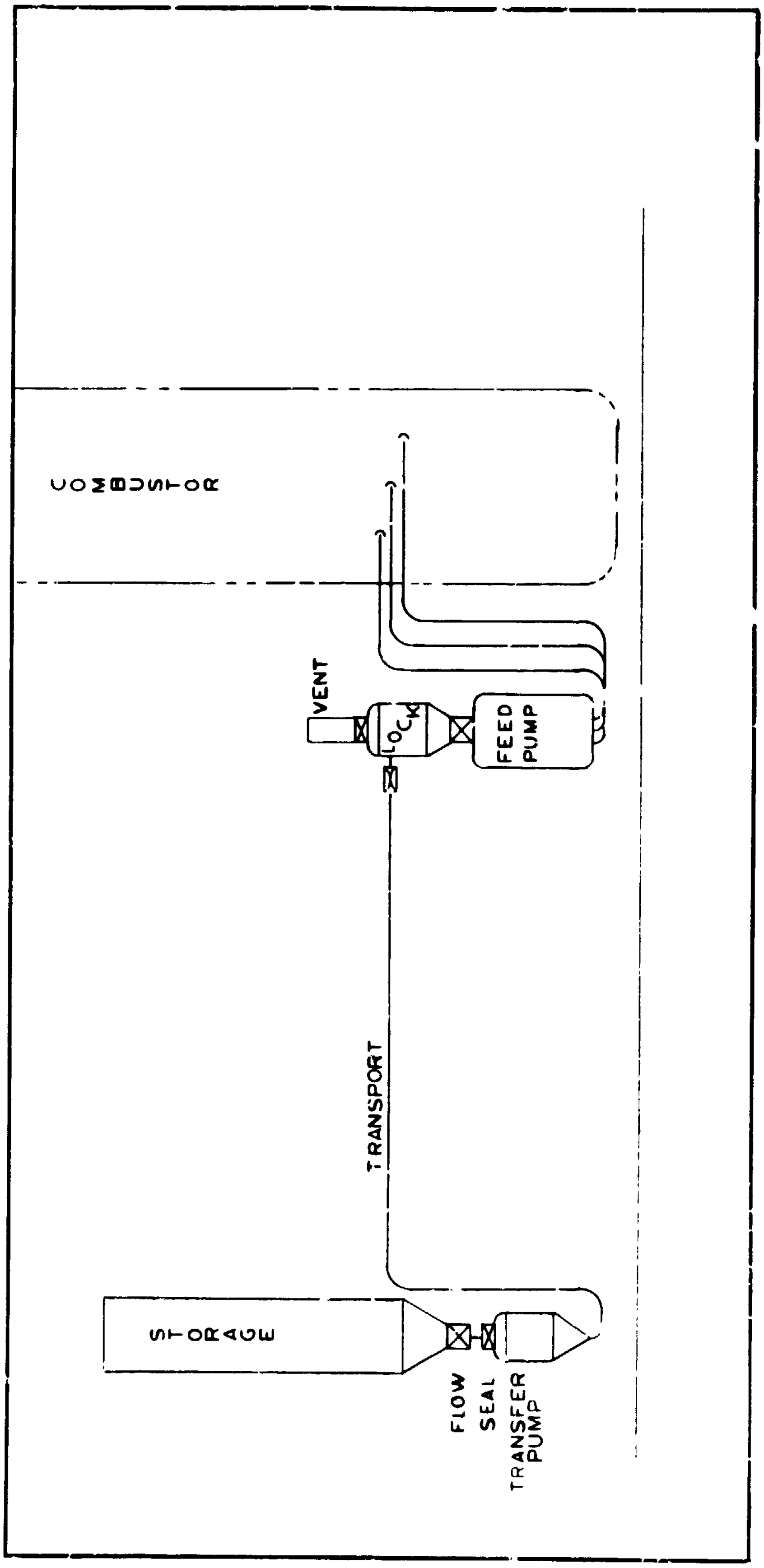

FIG. 2 .FBC TRANSFER & FEED SYSTEM

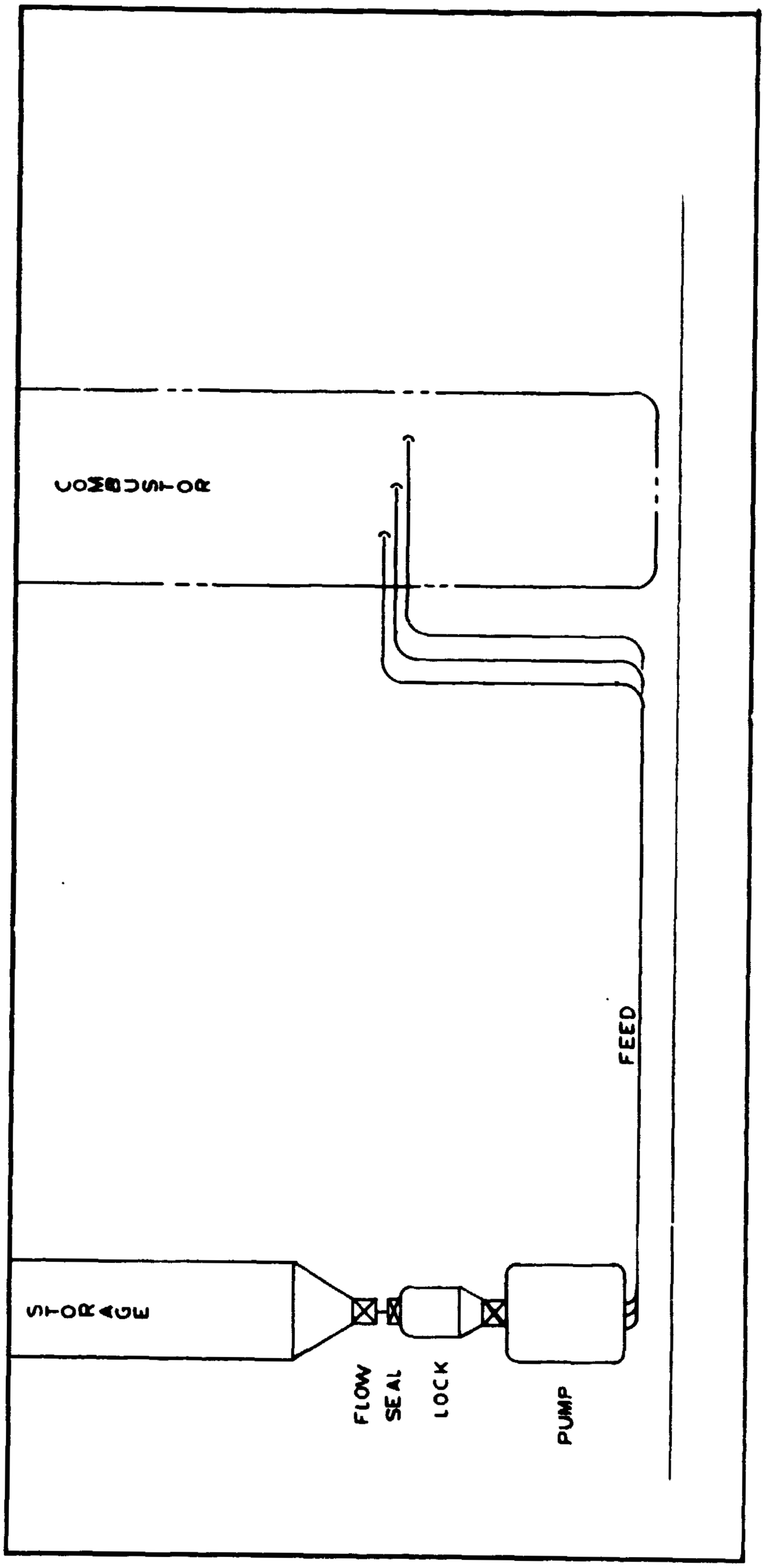

FIG. 3 PFBC FEED SYSTEM

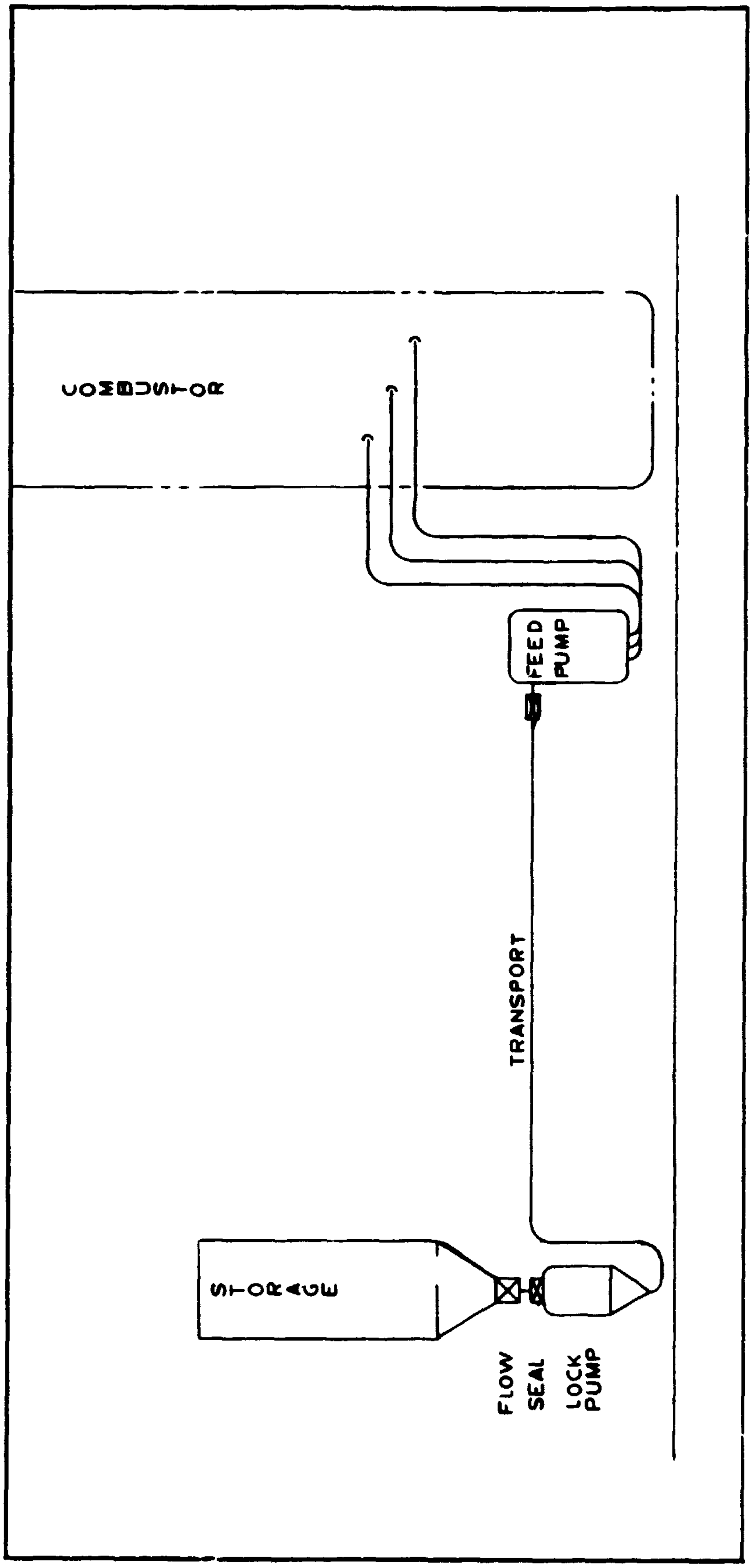

FIG. 4 PFBC LOCK FEED SYSTEM