DOE/PC/93156--T1

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FINAL REPORT

INTEGRATION OF THICKENER UNDERFLOW INTO THERMAL DRYER CIRCUIT

Program Research and Development Announcement (PRDA) Number
DE-RA22-92PC92250
Entitled
"POC-Scale Testing of Improved Coal Preparation Technologies and Equipment."

Contract Number:
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1. EXECUTIVE SUMMARY

A large number of coal preparation plants in the United States are troubled with coal fines and associated plant operation problems. As part of their process, these plants use thermal dryers for producing product coal, cyclones for first-stage recovery of coal fines, and wet scrubbers for the second-stage removal of coal fines carry-over from the dryer exhaust gas. The first challenge for these plants is to recover the clean ultra-fine coal captured in the scrubbers rather than to dispose of it in settling ponds. The second challenge is to mitigate the over-dry fine coal dusting problems in the dryer product.

Prior to the completion of this program, the difficulties of the first challenge involving the recovery and use of fine clean coal from the thermal dryer scrubber effluent had not been solved. The second challenge, controlling fine coal dusting, was previously met by applying a solution of surfactants and process water to the over-dry coal fraction. As a result of the demonstration provided by the performance of this program, the implementation of a simple process improvement, involving the use of a thickener in combination with a belt press, simultaneously solved both challenges: the de-dusting and the dryer scrubber effluent recovery issues.

The objective of this project was to:

- Use a clean coal thickener with a squeeze belt press to recover the ultra-fine coal in dryer scrubber effluent.
- Demonstrate that the coal-water mixture (CWM) produced from scrubber sludge of a thermal dryer can be used as a dust suppressant.

The thickener/belt press system has increased the production of JWRI Mine Number 4 by approximately 0.7%. This production increase was accomplished by recovering and re-using 3 metric tons/hr (3.3 tons/hr) of coal fines that were previously sent to holding ponds, returning this as a 50% CWM to de-dust the 430 metric tons/hr (470 tons/hr) of existing dryer production.

The system has been in operation for the past 8 months. Apart from a few initial shake-down issues, the equipment has run smoothly and reliably.

2. BACKGROUND

2.1 Overview

A large number of coal preparation plants in the United States are troubled with coal fines and associated plant operation problems. As part of their process, these plants use thermal dryers for producing product coal, cyclones for first-stage recovery of coal fines, and wet scrubbers for the second-stage removal of coal fines carry-over from the dryer exhaust gas. The first challenge for these plants is to recover the clean ultra-fine coal captured in the scrubbers rather than to dispose of it in settling ponds. The second challenge is to mitigate the over-dry fine coal dusting problems in the dryer product.

Prior to the completion of this program, the difficulties of the first challenge involving the recovery and use of fine clean coal from the thermal dryer scrubber effluent had not been solved. The second challenge, controlling fine coal dusting, was previously met by applying a solution of surfactants and process water to the over-dry coal fraction. As a result of the demonstration provided by the performance of this program, the use of a simple process improvement, involving the use of a thickener in combination with a belt press, simultaneously solved both challenges: the de-dusting and the dryer scrubber effluent recovery issues.

Figure 2.1 is a schematic of a conventional coal processing plant. Process water produced in the thickener is needed for both wet scrubber and de-dusting operations in the dryer circuit, as well as in the balance of plant. Ultra-fine clean coal from the thermal dryer circuit is sent to the central continuous thickener, where it is mixed with high-ash tailings from the balance of plant. The resultant high-ash sludge is pumped to a clarification pond for final dewatering.

Figure 2.2 is a schematic describing the improved coal processing plant. The fundamental improvement in this design involves segregating the clean coal fines from the high-ash tailings, instead of mixing them in a common thickener. This separation of recoverable coal from high-ash tailings allows a new, fine coal dewatering loop to be added, ultimately producing a concentrated coal-water mixture (CWM) that is used to de-dust the over-dry thermal dryer product. Equipment used in the new dewatering loop consists of a fine coal thickener, which serves as both a scrubber holding tank and a first-stage concentrator; followed by a squeeze belt press, which performs the final stage of dewatering. Only minimal changes are required to utilize CWM in place of water as the de-dusting agent. Using this process flow design, a coal preparation plant can recover a valuable product from its waste stream and use this material as an effective dust suppressant.

In summary, the objective of this project was to:

- Use a clean coal thickener with a squeeze belt press to recover the ultra-fine coal in dryer scrubber effluent.
- Demonstrate that the (CWM) produced from scrubber sludge of a thermal dryer can be used as a dust suppressant.

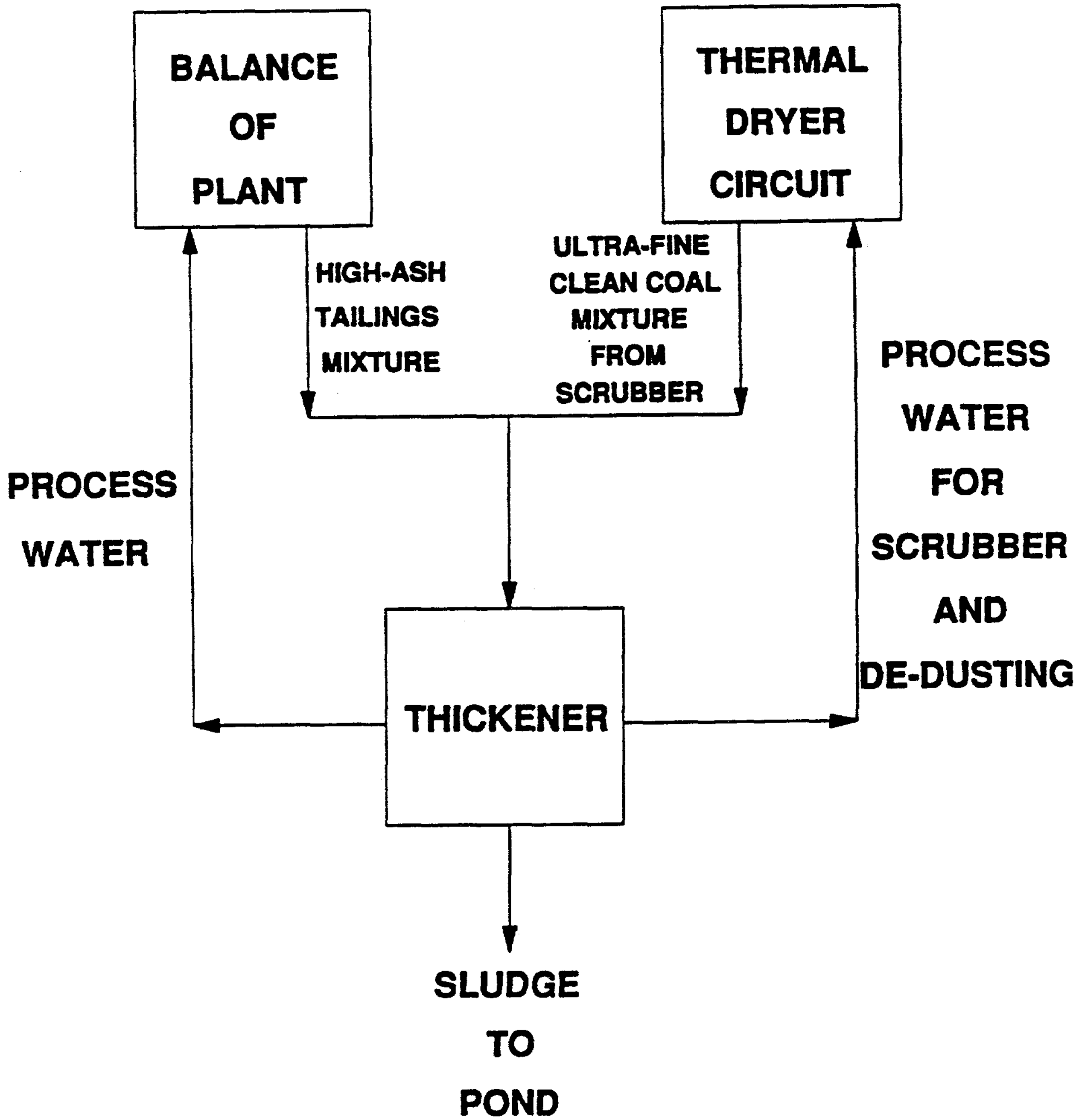

Figure 2.1 Conventional Processing Plant Coal Thickener Arrangement

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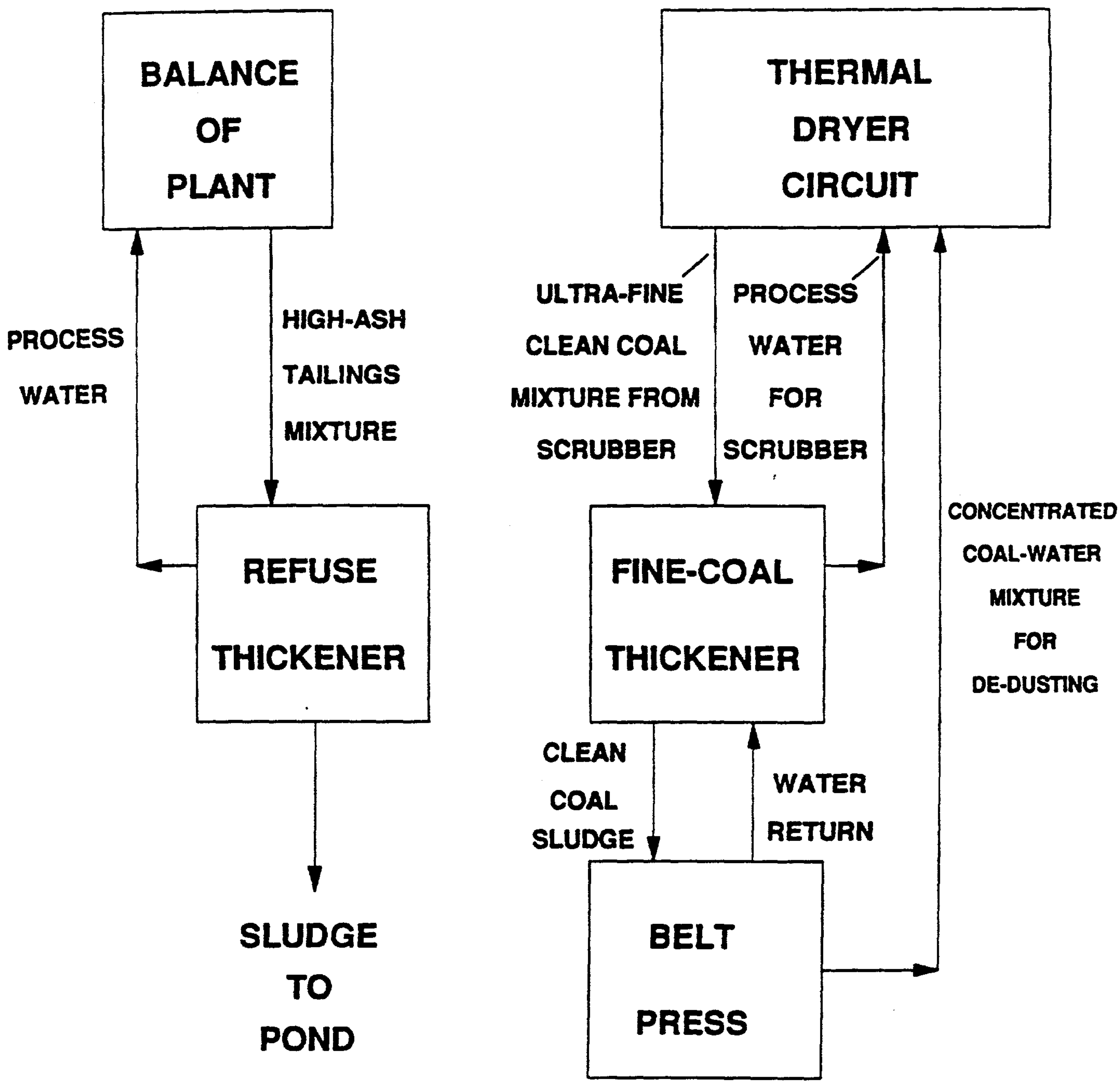

Figure 2.2 Proposed Fine Circuit Modification

2.2 Discussion Of A Larger Need For Ultra-Fine Coal Recovery And Use

Coal fines are a natural and inevitable consequence of conventional mining, coal preparation, and handling operations. These fines present problems for all aspects of the coal utilization sector from the mine, to the coal preparation plant, through transportation, and storage and handling for the end user.

Recently, the 1990 amendments to the Clean Air Act (CAA), Public Law 101-549, provided major incentives for deeper sulfur removal (beneficiation) of coal. These incentives produce an economic justification for the use of lower-sulfur coals in both existing and future boilers. Generally, only moderately increased crushing is required to cost-effectively liberate additional pyritic sulfur and other mineral impurities in conventional, low-cost cleaning equipment. However, such moderate increases in comminution will greatly increase the quantity of coal fines, along with the technical problems of handling the integration of increased coal fines in the preparation plant circuit. These technical problems are perceived by the coal preparation industry as sufficiently serious to slow the growth of deeper sulfur removal, and will thereby contribute to an erosion of coal's market share.

For the coal preparation plant, fines represent several challenges. First, if the fines are not cleaned at the plant, they must either be mixed with the coarse material and thereby degrade the quality of the final product (lower heating value, higher sulfur, ash and moisture content), or be discarded which increases the amount of refuse in settling ponds. Second, due to the small size of these particles, they tend to have a very high specific surface area and as such tend to absorb a significant amount of moisture during any cleaning operation, such as froth flotation. This higher moisture content can result in the need for additional unit operations at the preparation plant, such as thermal drying, to meet customer specifications. Conventional coal thermal drying systems reduce the overall moisture level of the product, but at the expense of overdrying the finest product fraction. This practice contributes to significant fugitive dust emissions which require expensive surfactants and polymers to control.

2.3 Proposed Solution

To deal with the problems associated with the integration of fine coal circuits with the balance of the coal preparation plant, a program was proposed to perform a Proof-of-Concept (POC) demonstration of an Emerging coal preparation Technology (ET) for handling of fines which improves overall plant productivity and performance.

With any coal drying system a small amount of low ash, ultra fine coal is collected in wet and/or dry exhaust gas cleaning processes. Coal fines collected in dry particulate collection systems are usually recycled and mixed with the dry product coal, resulting in a dust generation problem. Dilute wet scrubber effluent is generally sent to a thickener; the resultant underflow sludge, containing clean coal, is sent to settle in on-site ponds.

Historically, the effluent from coal thermal dryer exhaust gas scrubbers has been mixed with tailings from the coal cleaning plant. Consequently, this low-ash coal becomes mixed with and diluted by a much larger flow of high ash tailings. There has been insufficient economic return to justify recovering clean coal from such combined thickener underflow streams or impoundments.

Recently, however, increased quantities of fines have been produced (or are predicted to be produced) in coal preparation plants. These underflow fines have come from the increased use of mechanical mining equipment, which results in the use of wet cleaning methods to clean this fine coal fraction. Predictions of increased fines production have come due to the 1990 CAA amendments, which portend greater deep cleaning of coal. Consequently, recovery and use of these increased coal fines will eventually become an economic necessity.

This program proposed to use a combination of a clean coal thickener with a squeeze belt press to recover the ultra-fine coal in dryer scrubber effluent before it is mixed in with the balance-of-plant tailings. As an additional essential part of this program, we proposed to demonstrate that the coal-water mixture (CWM) produced from the scrubber sludge of a thermal dryer can be used as a dust suppressant. The net effect of these two coal circuit changes is to integrate the thickener underflow into the thermal dryer circuit. This essentially closes the loop and permits maximum efficiency from the system, by recycling a former waste stream (sludge) as an effective dust suppressant.

It was the objective of this proposal to successfully demonstrate the utilization of thickener underflow-based CWM for dust suppression at the preparation plant, at scales up to 7.3 metric tons/hr (8 tons/hr) of CWM. This scale of testing provided meaningful results for coal preparation plant operators to evaluate this technology for their particular plant's operation.

2.4 Project Team

The program was performed by Tecogen and Jim Walter Resources, Inc.

Tecogen, the Prime Contractor, beneficially applies the company's core technologies to meet evolving national and international needs. Our objective for this program was to apply our extensive coal technology in an emerging market.

JWRI produces 9.1 million metric tons (10 million short tons) of coal annually, and is involved in several areas at the forefront of coal technologies. Their objective for this program was to install the first full-scale integrated CWM recovery/dust suppression loop in one of their operating plants, Mine Number 4, and continue their technical leadership.

2.5 Anticipated Challenges

The major challenges to be surmounted in the program existed in the areas of sludge dewatering, slurry handling, slurry atomization, and dust suppression. Sludge dewatering has been a problem area in the coal industry in general, including at JWRI. Proper selection of mechanical dewatering equipment has been identified as the most critical task of this program. For example, centrifugation can be used on a 50% feed slurry of 1.9 cm by 0.64 (3/4- by 1/4-in.) stoker-grade coal to reduce the surface moisture level to 6%. Unfortunately, centrifuges have not yet proven to be satisfactory in service on minus 44 micron (-325 mesh) coal fines sludge, due to the much smaller particle size in the coal fines sludge (9 micron average particle size), as well as the much lower solids loading in the sludge (10 – 20% solids).

Other methods of producing pumpable CWM have also been explored, but each possesses individual drawbacks. For example, pressure filters may be able to produce a cake-like material from ultra-fine coal. However, this equipment would be of little use to a coal producer, as water would have to be remixed with the cake to produce a pumpable CWM. Alternately, vacuum filters can be specified to concentrate such ultra-fine coal. However, blinding of the media is a major problem associated with vacuum filtration of such ultra-fine coal mixtures.

This program demonstrated that the use of a belt press on the underflow from a thickener, is the most technically viable and cost-effective means of producing a pumpable CWM from coal sludge that is suitable for de-dusting dry, fine coal. This type of equipment has produced excellent results in a wide variety of commercial applications ranging from fine coal refuse, aerobically digested sludge, fume filter washings, marble quarry waste, to heavy metal precipitation treatments. Data from one such representative fine coal refuse application indicates that a 1-meter belt press can process 300 kg/hr (dry basis) of an anthracite sludge and produce >60% (dry basis) product. Consequently, application of the belt press for recovering a maximum of 7.3 metric tons/hr (8 tons/hr) of 50% CWM from 15% thickener underflow sludge is well within the capabilities of commercially-available machines.

CWM handling and slurry atomization have been identified as two additional areas which needed to be addressed in this program. For example, improper pumping, storage or atomization of slurry may lead to maintenance difficulties for the process equipment or to the expensive loss of mine production capability. However, both project team members have broad experience in slurry handling and atomization that can be comfortably scaled-up to apply to the proposed program. JWRI has been successfully developing CWM technology for 10 years. In particular, the project team has demonstrated CWM handling and atomization at one-fourth to one-seventh scale of the proposed project, which represents a conservative scale-up to the 7.3 metric tons/hr (8 tons/hr) CWM flowrate of the proposed program. Consequently, CWM handling and slurry atomization is not expected to be a major problem area.

Suitable commercial procedures exist for suppressing coal fines dust using dilute aqueous solutions of surfactants and chemicals. However, the addition of fine coal to the dilute surfactant-laden dust suppression solutions requires a change to the concentration or the type of chemical needed to maintain suitable low dust levels. The project team used standard engineering practice to verify the exact surfactants as well as their concentration in this program.

2.6 Original System

The coal preparation plant at JWRI Mine Number 4 has a design point capacity of 544 metric tons/hr (600 short tons/hr) of clean coal. The coal cleaning circuits, shown in Figure 2.3, are operated continuously on a five day work week. Most in-plant coal transporting is done by 0.91 meter-wide (36 inch-wide) conveyor belts. Raw coal is delivered to the 22,700 metric ton (25,000 short ton) stacker, where it awaits transfer to the preparation plant. In the plant, sizing, cleaning, and drying operations are conducted to produce the required product coal specifications.

The dryer system at Mine Number 4 has a design dry product throughput of 644 metric tons/hr (710 tons/hr). The coal drying circuit is operated continuously on a four-day work week, allowing one day for dryer maintenance. Figure 2.4 shows a plan view of the general arrangement of equipment in the dryer plant. This view details additional support systems, such as the fluidized bed dryer's combustion system, dust collection cyclones, and the exhaust gas

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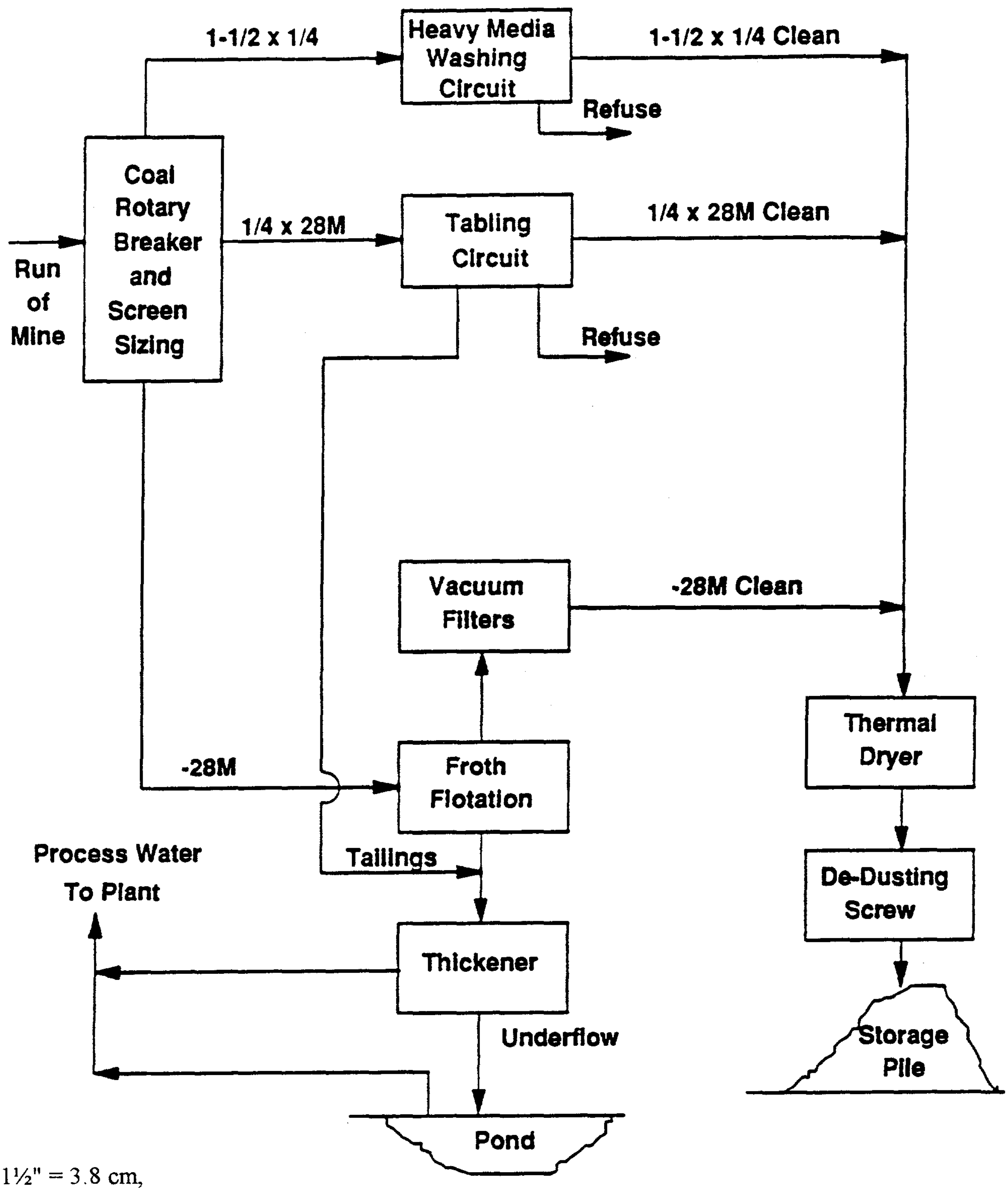

1½" = 3.8 cm,

¼" = 0.64 cm

Figure 2.3 Overall Coal Preparation Plant at JWRI Mine Number 4

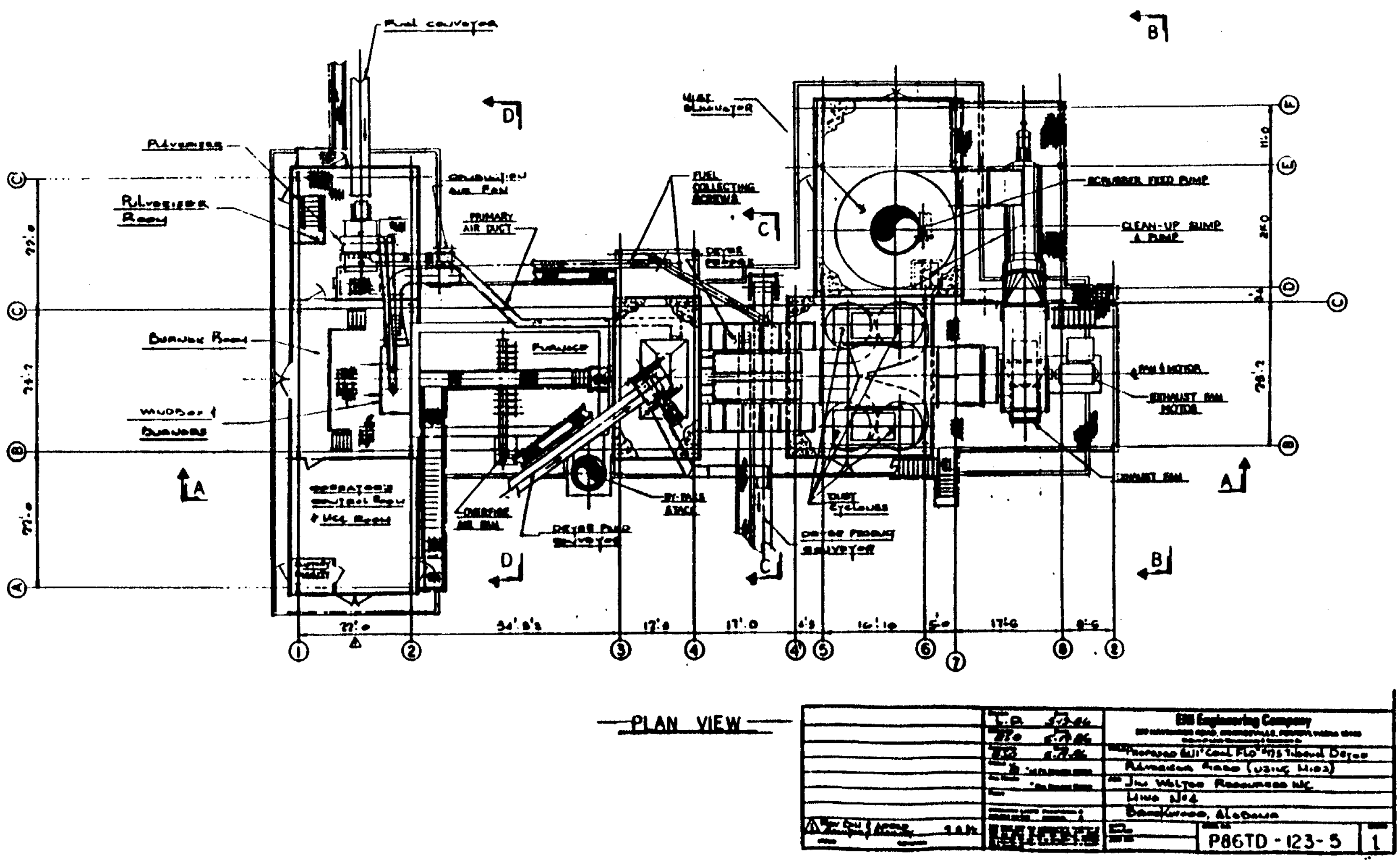

Figure 2.4 Coal Preparation Plant Plan View

scrubber. Figures 2.5 and 2.6 illustrate four elevation views of the coal preparation facility, providing a better visualization of the dryer site.

The dryer inlet coal moisture content was originally 13%. The fluidized bed dryer evaporation rate is 36.3 metric tons/hr (40 short tons/hr) of water, starting with 680.3 metric tons/hr (750 tons/hr) of wet feed. Dry product coal contains 7% moisture, resulting in the design dryer production rate of 644 metric tons/hr (710 tons/hr) of coal. Design thermal input to the dryer is 44 MW (150 MMBtuh). The dryer is fueled by a portion of the dust collected by the cyclones.

Dry fine product coal collected in the four cyclones is routed to two screw conveyors. A portion of this fine coal passes through other screw conveyors to the burner system of the plant. The balance is de-dusted with a chemical/water solution, then passes through chutes to the dryer product conveyor. Dry product is moved by belt to the 22,700 metric ton (25,000 short ton) dry product stockpile. Ample provisions are made for truck and future rail loadout at the site.

Figure 2.7 is a drawing of the original static thickener at JWRI's Mine Number 4 coal dryer plant. Relative to the preparation plant's dryer subsystem, the static thickener serves as the holding tank for the exhaust gas scrubber liquor, as well as providing clear water for the scrubber system. Figure 2.8 details the interconnection between the thermal dryer, cyclones, wet scrubber, and thickener. Ultimately, clean coal fines concentrated in the thickener are pumped to one of three clarifying ponds. JWRI currently pays removal costs of \$3.31/metric ton (\$3/ton) to "muck out" coal fines for ultimate disposal.

2.7 New System Plan

The proposed change in the process was to install a Parkson belt press after the existing static thickener, as shown in Figure 2.9. This thickener/belt press combination will recover ultra-fine coal from the thickener underflow, thereby recovering and recycling previously wasted coal fines that would have otherwise been sent to the adjacent pond.

Figure 2.10 illustrates the arrangement of the additional oversize protection sieve, concentrated CWM holding tank, and pumps required to complete the system. A plant-specific reason necessitates an oversize protection sieve for this process: coarse coal conveyors travel over the thickener, and could possibly deposit oversize material in the system. This sieve will protect the belt press from excessive wear and associated increased maintenance requirements. The CWM holding tank is supplied to even-out the expected process-related variations.

Figure 2.11 is a detailed schematic of the Parkson belt press, showing the actual equipment packaging arrangement. Resultant CWM from the new thickener/belt press system is either used as de-dusting fluid for the two existing 0.51 meter (20-inch) diameter mixing screws, thereby using the coal fines to agglomerate with and de-dust the fine dry coal product or is added as a cake to the coal pile. Four to five atomizers will be used in each screw, depending on the final CWM properties. A conservative 0.1 kilogram of atomizing air per kilogram of slurry is anticipated to provide the required degree of slurry atomization.

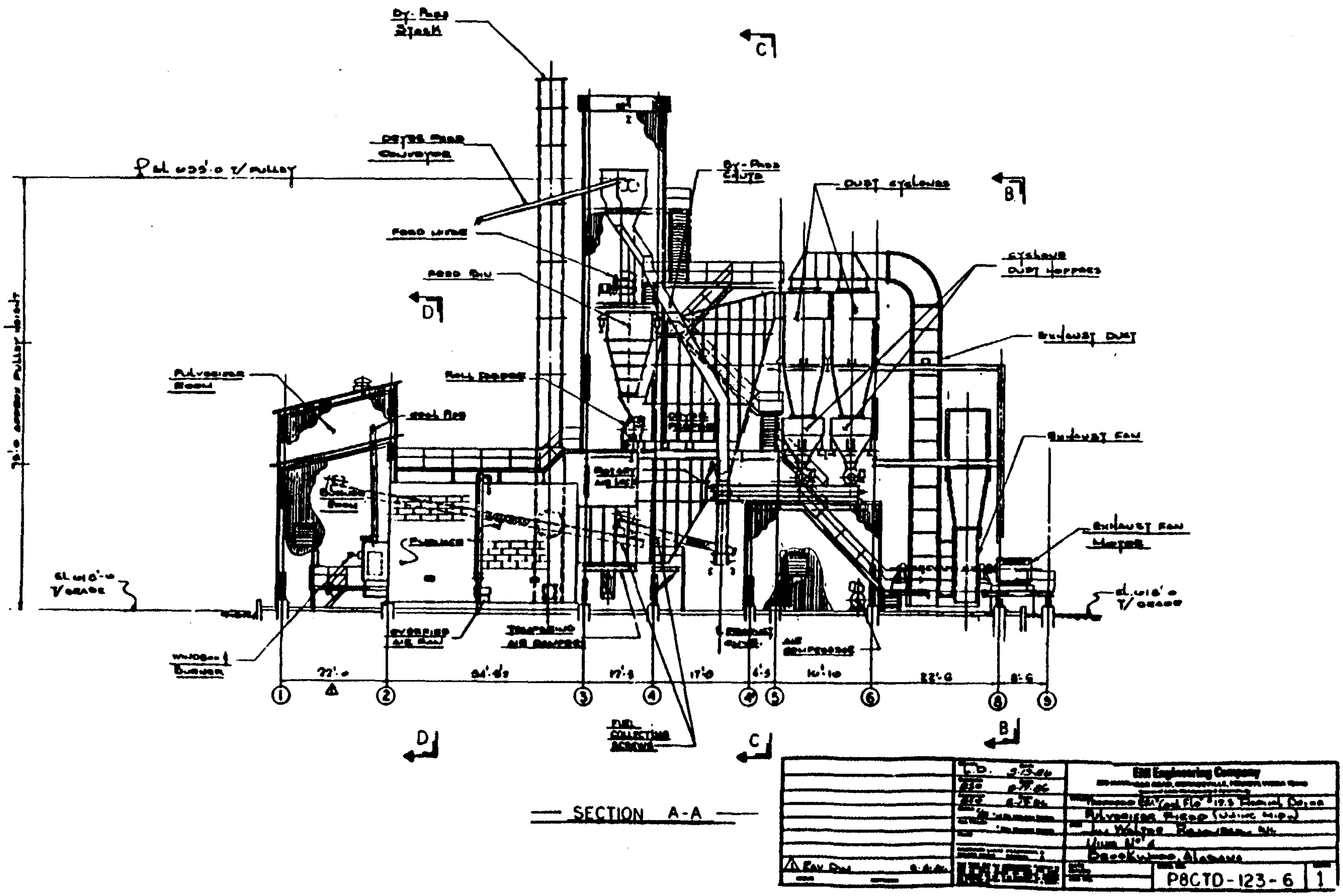

Figure 2.5 One Coal Preparation Plant Elevation View

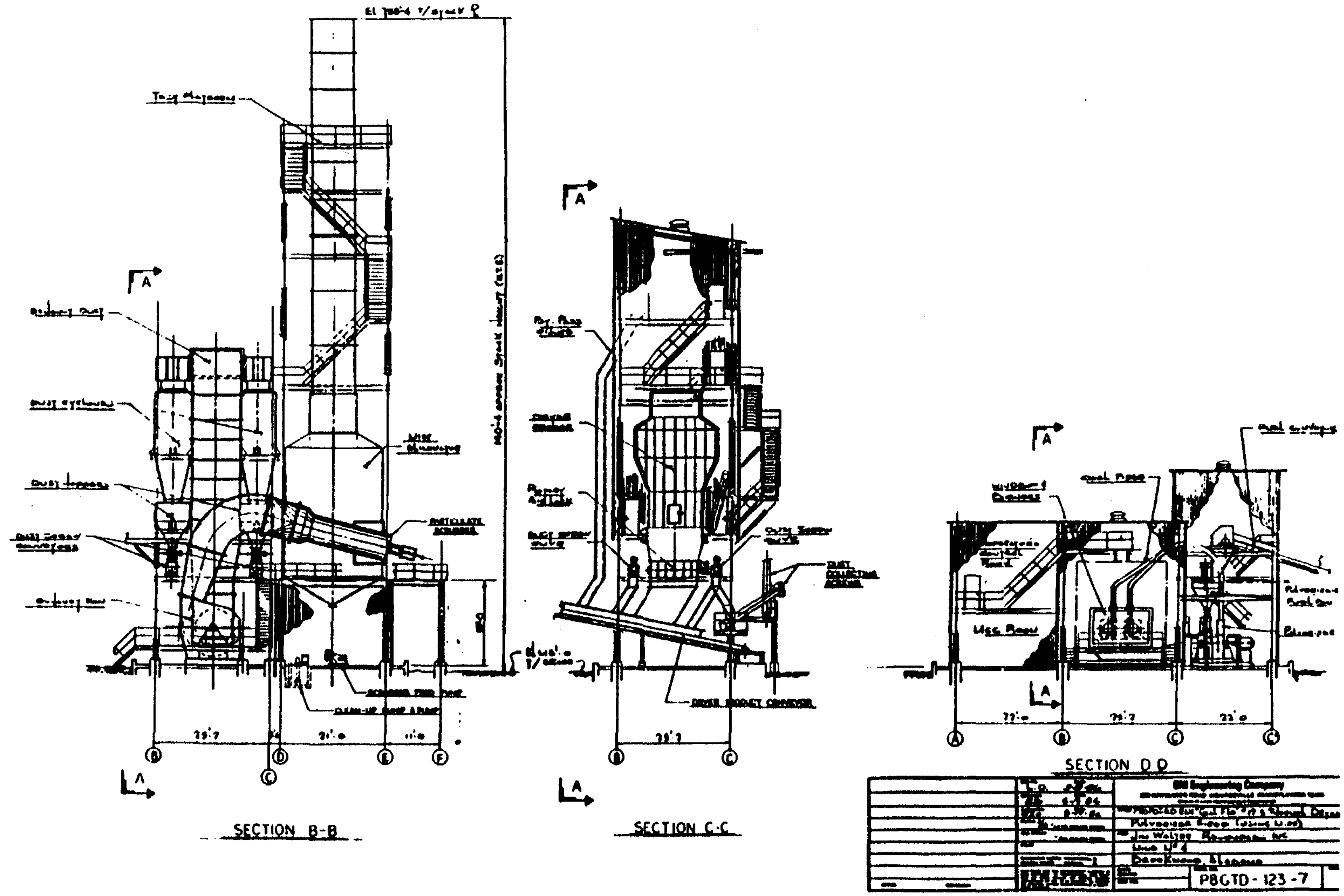

Figure 2.6 Three Coal Preparation Plant Elevation Views

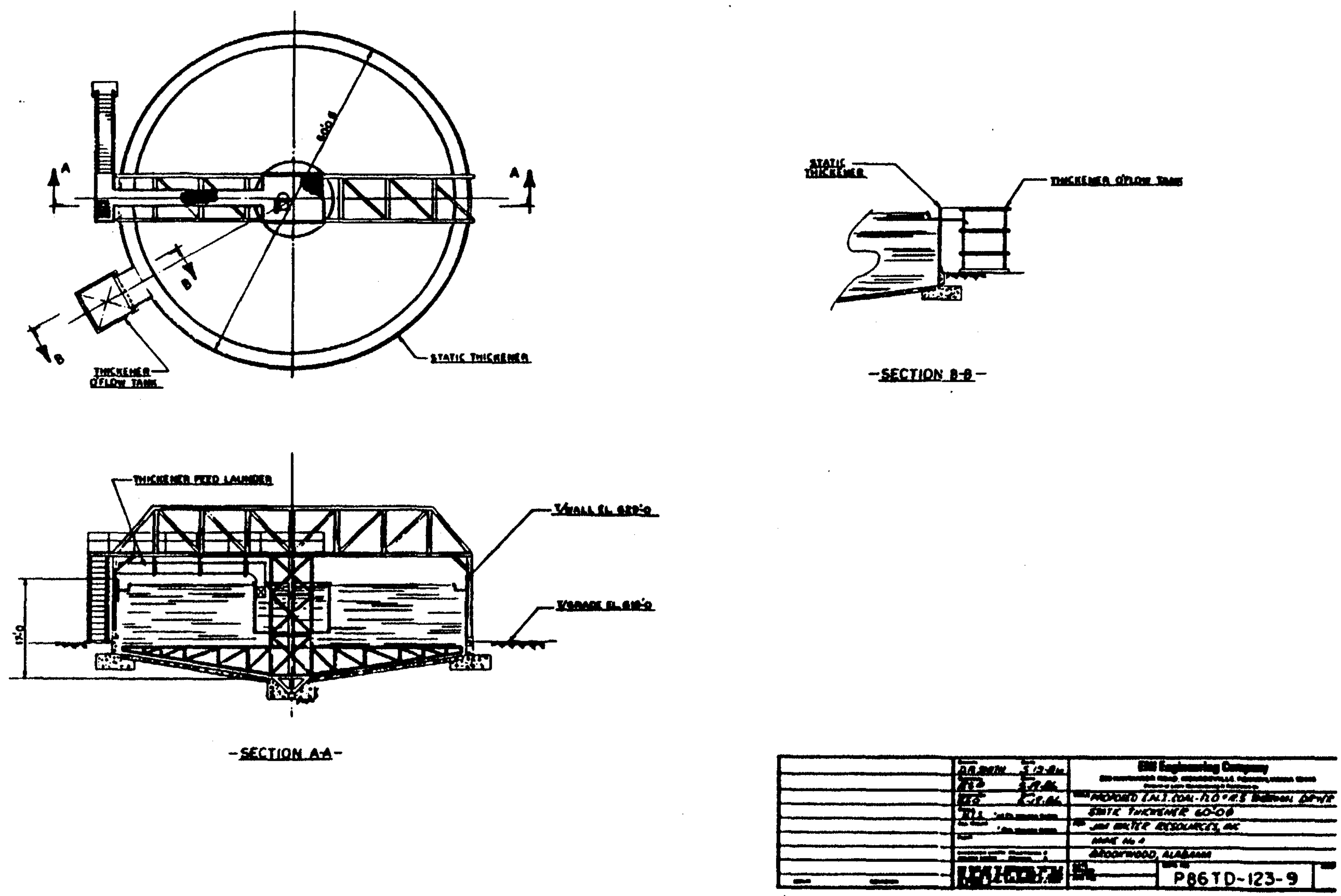

Figure 2.7 Existing JWRI Static Thickener

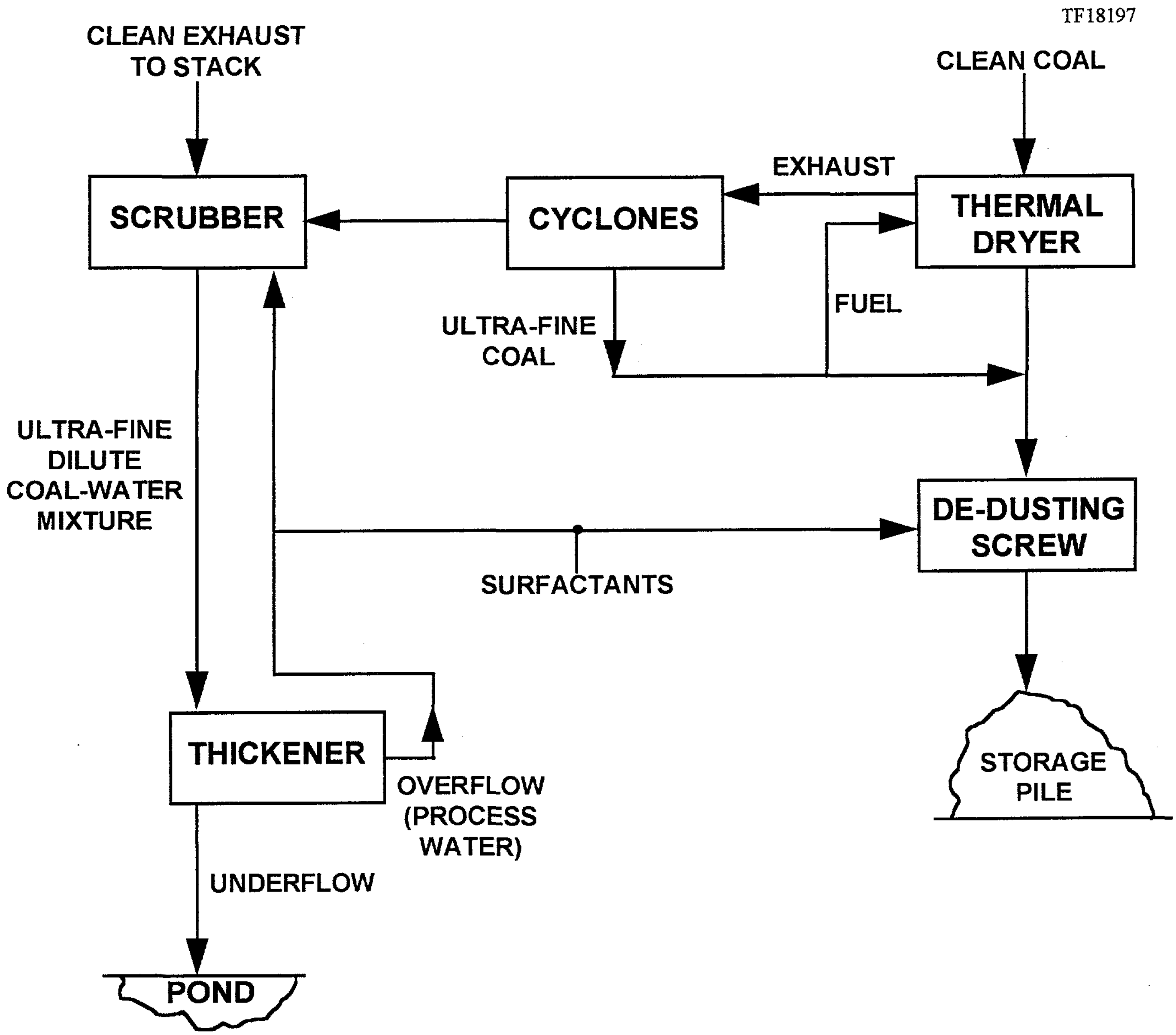

Figure 2.8 Relation of Thickener to Scrubber

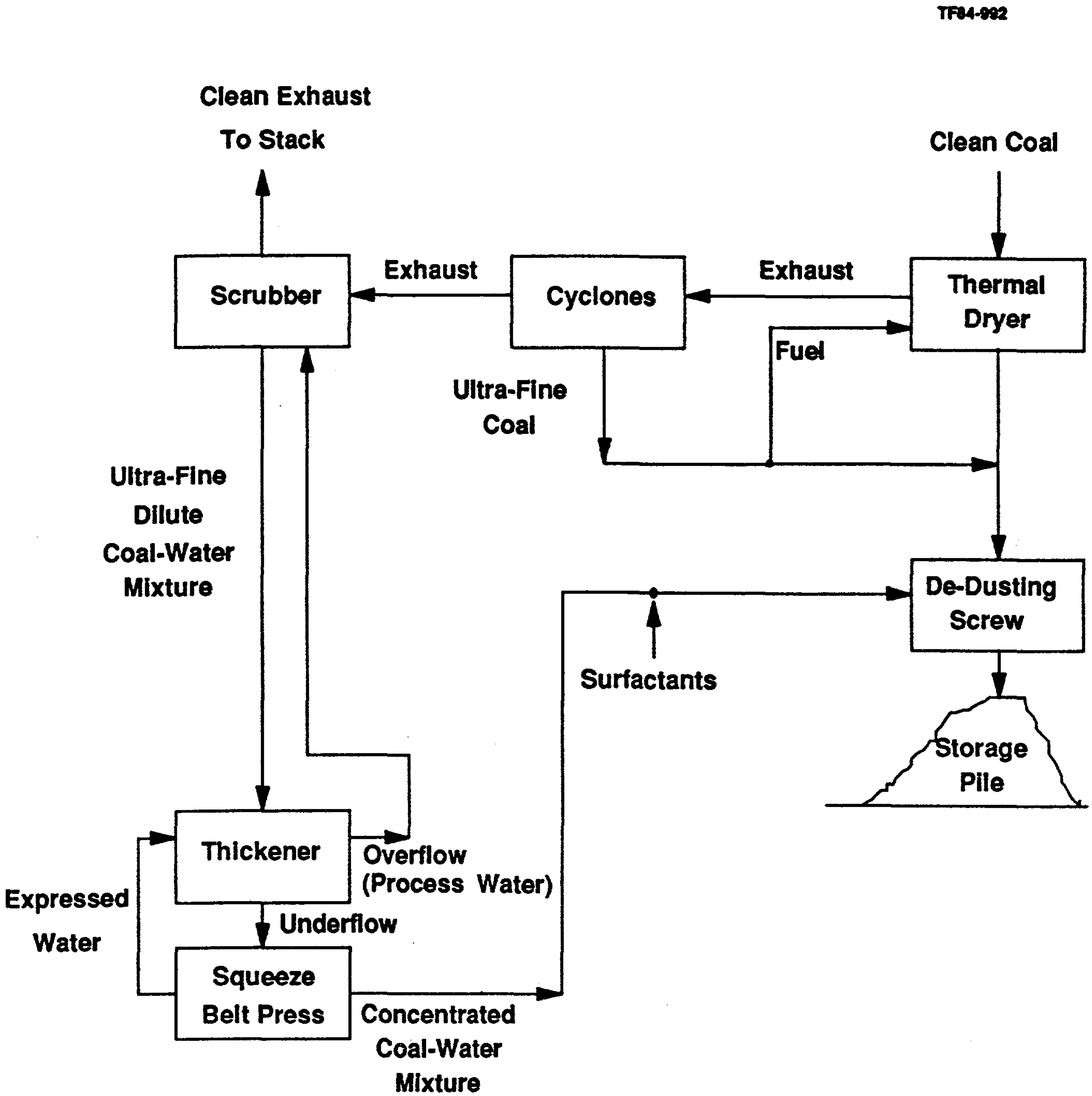

Figure 2.9 Proposed Belt Press Integrated to Thickener Underflow Stream

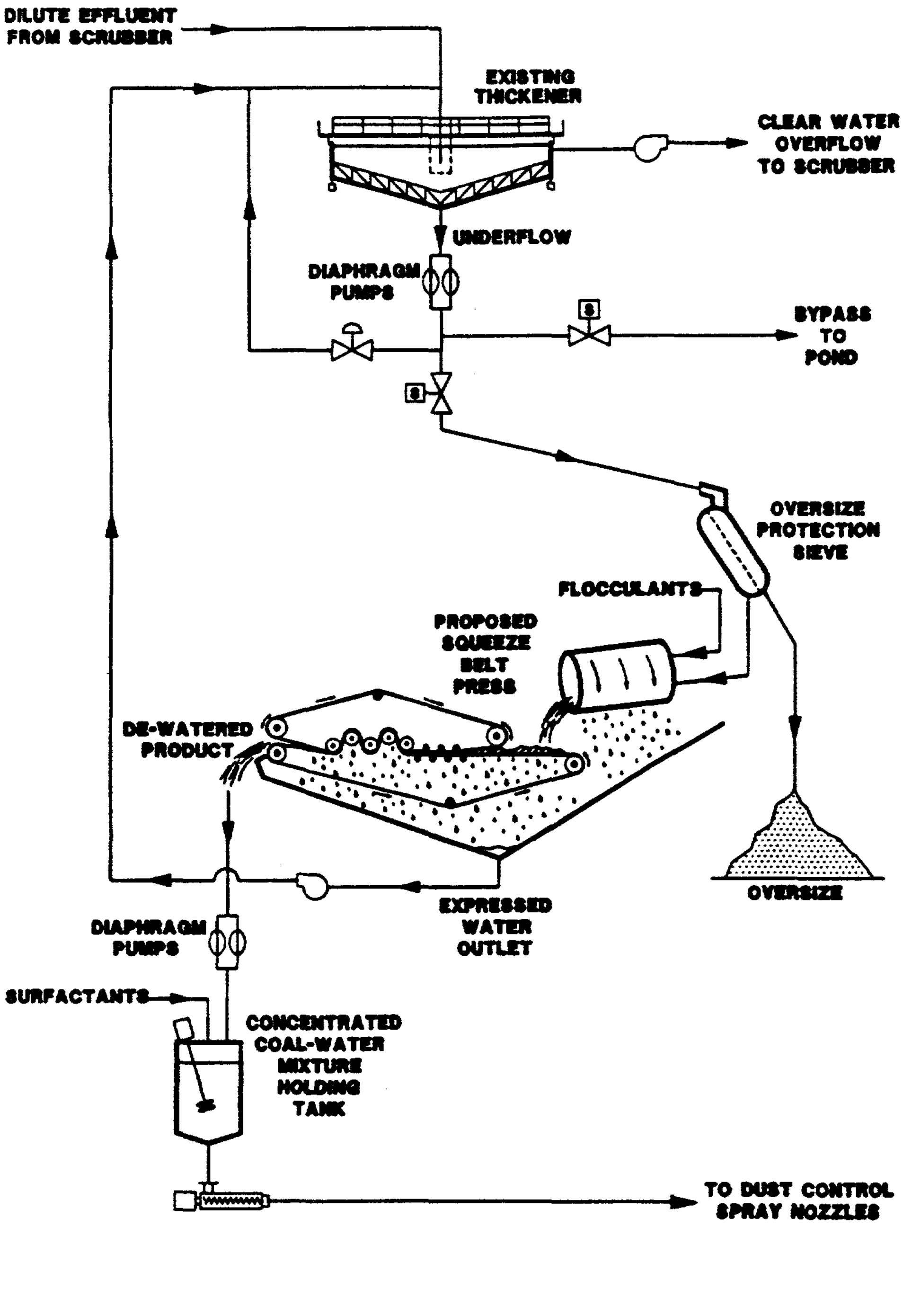

Figure 2.10 Proposed Modification to Thickener Underflow Stream

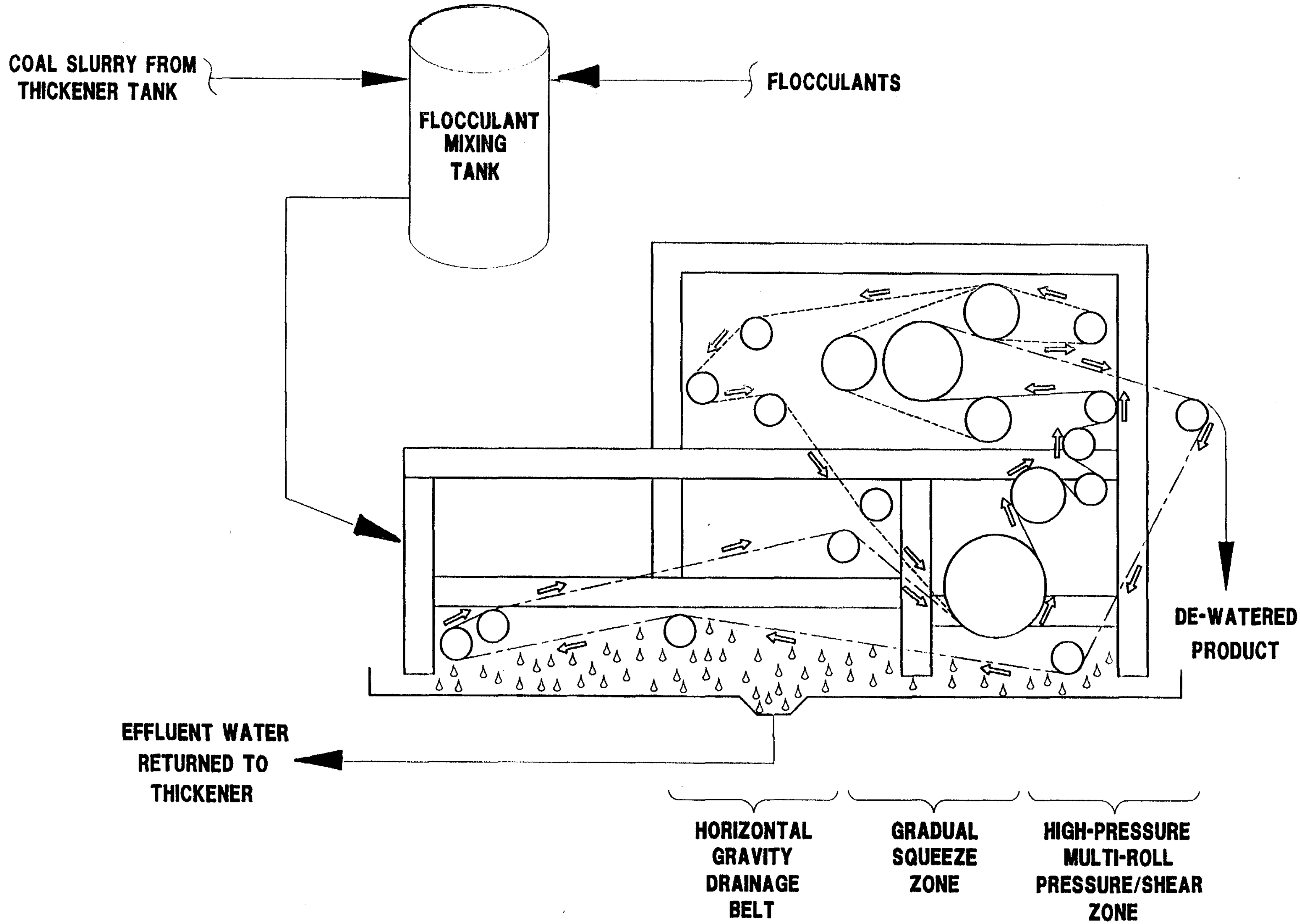

Figure 2.11 Parkson Belt Press Schematic

2.8 Discussion of Goals and Objectives of the Program

The goals of this program were to address the problems associated with the integration of fine coal circuits with the balance of the plant, by performing a POC demonstration of the technical advantages and improved economics resulting from using a thickener/belt press ET to dewater and recycle coal fines at a commercial coal preparation facility.

The technical advantages of the thickener/belt press equipment that were demonstrated include:

- Elimination of 3 metric tons/hr (3.3 tons/hr) of coal fines from JWRI settling ponds, by recovering and recycling fines into the dry product coal.
- Production of pumpable slurry in a simple, once-through process, without a need to bypass and remix raw feedstock with the dewatered product.
- Continuous equipment operation under a variety of operating feed conditions.
- Easily controlled slurry product moisture content, which will be essential for proper control of the de-dusting fluid application process.
- Low plant space requirements, essential for these retrofit installations.
- Low and easily performed maintenance requirements.

The improved economics from commercially recovering coal fines with a thickener/belt press combination were expected to include:

- Maximizing the net production and sales of useful coal from the plant, by recovering and reusing previously wasted low ash, ultra fine coal.
- Use of processed scrubber effluent for de-dusting purposes to reduce the flow rate of scrubber sludge to the settling ponds which by lowering demands on the plant's clarification system will reduce the associated operating costs.
- A potential reduction in the requirements for de-dusting surfactants and polymers.

2.9 Summary

For a number of reasons, production of coal fines will continue to increase in the U.S. Economic operations are needed that address the challenges associated with the anticipated increased fines production. Two common difficulties involving coal fines have been identified: a need for eliminating the common practice of sacrificing clean ultra-fine coal mixtures, and a requirement for mitigating over-dry fine coal dusting problems in the dryer product. A simple flow sheet modification will overcome both of these difficulties.

The proposed modification involved:

- Segregating clean coal sludge mixture from balance-of-plant tailings.
- Using a clean coal thickener in combination with a belt press to recover CWM.
- Using the product CWM to de-dust the over-dry fraction of dryer product coal.

This modification was shown to have excellent technical merit, as it utilizes a technology that has been extensively proven in dewatering fine coal refuse, it provides approximately a 0.7% boost in plant product coal production, it has a simple payback period that is less than one year, and provides the environmental benefit of reducing solid waste emissions to the clarifying ponds.

In summary, this program was intended to demonstrate the technical and economic benefits that accrue from the use of a thickener/belt press system on coal fines. Without increasing the manpower requirements of the plant, addition of the thickener and belt press increased coal production, thereby increasing coal sales, providing an economic boost to the plant's operation.

3. SYSTEM PERFORMANCE ACCOMPLISHMENTS

3.1 Technical Accomplishments

The thickener/belt press system has increased the production of JWRI Mine Number 4 by approximately 0.7%. This production increase was accomplished by recovering and re-using 3 metric tons/hr (3.3 tons/hr) of coal fines that were previously sent to holding ponds, returning this as a 50% CWM to de-dust the 430 metric tons/hr (470 tons/hr) of existing dryer production.

The system has been in operation for the past 8 months. Apart from a few initial shake-down issues, the equipment has run smoothly and reliably.

Table 3.1 displays the capital cost of the equipment installed as part of this program. A total of $339,003 was spent with the largest purchase being the belt press supplied by Parkson for $144,000.

Table 3.2 displays the monthly coal processed along with the operating and maintenance costs. This table describes the costs and revenue for the first six months following the installation. Coal recovery increased from about 2.3 metric tons/hr (2.5 tons/hr) during the first few months after the installation to about 3 metric tons/hr (3.3 tons/hr) during the last two months of the test period when the days of operation were increased. Simple payback was observed to decrease from about 2 years to less than one year with the increased utilization of the equipment.

Mixing of the recovered slurried coal fines with the product coal is performed with an existing mixing screw. This process used the recovered CWM for providing dust suppression on the over-dry portion of the product coal. This use of CWM eliminated the existing practice of de-dusting with mixed process water/surfactant solution, reducing the plant's process water usage by 60 lpm (16 gpm).

An improvement in effluent water clarity resulted from use of the thickener/belt press system. This improvement resulted from the elimination of the 3 metric tons/hr (3.3 tons/hr) of thickened solids being sent to the clarification ponds from the thickener, along with the 344 l/min (91 gal/min) of associated wastewater.

Table 3.1
Jim Walter Resources Inc.
Capital Cost Summary

EQUIPMENT IDENTIFICATION	NUMBER	CAPACITY OR SIZE*	COST $
Process Equipment			
Belt Press	BP-50	2 meter	144000
Rotary Strainer	RS-70	125 GPM	5500
Air Compressor	AC-53	16.5 CFM	1750
Basket Strainer 1	BS-60	8"	900
Basket Strainer 2	BS-95	4"	300
Inline Static Mixer	IM-62	2"	350
Refrigerant Dryer	RD-80	20 CFM	500
Diverter Chute	DC-52	79"x84"	11000
Polymer Blender	PB-15	600 GPH	5200
Valves	HV-xxx		2200
Regulators	PR-xxx		400
Vent Fan		24"	400
Pumps			
Underflow Pump	P-161	52 GPM	4600
Slurry Pump	P-195	17 GPM	3200
Water Pump	P-171	125 GPM	2100
By-Pass Pump	P-155	200 GPM	3400
Polymer Pump	P-125	2 GPH	1944
Surfactant Pump	P-190	11 GPH	804
Recirculation Pump	P-110	30 GPM	400
Process Vessel			
Flocculant Holding Tank 1	TK-10	800 gal	1285
Flocculant Holding Tank 2	TK-20	800 gal	1285
By-Pass Holding Tank	TK-55	800 gal	1750
Flocculant Tank	TK-51	120 gal	3500
Dispersal Tank	TK-95	500 gal	16400
Surfactant Tank	TK-90	850 gal	1285
Sensing Equipment			
Underflow Flow Meter	FM-60	2"	6650
Slurry Flow Meter	FM-95	1.5"	6350
Water Rotometer	FM-51	10 GPM	50
Level Probes	LE-xxx		2700
Level Switches	LS-xxx		1400
Pressure Switches	PS-xxx	0-250 psi	250
Pressure Gages	PG-xxx	0-300 PSI	200
Control System			
Control Computer			7200
Control Cabinet			1400
Displays			1500
Underflow Speed Controler			2000
Slurry Speed Controler			1700
Motor Starters			1400
Distribution Panel		200 AMP	3500
Disconnects			1250
Installation			
Mechanical			33000
Structural			20000
Electrical			34000

*These are installed process equipment capacities and sizes and are reported as provided.

Table 3.2
Jim Walter Resources Inc.
Manufacturing Cost Summary *, **

Production Revenues/Month	June 94	July 94	Aug 94	Sept 94	Oct 94	Nov 94	AVE
Dryer Input (wet tons/month)							
no.4	165281	166719	109911	148496	224059	234023	174748
no.5	1399		1276	1763	2792	2066	1549
no.3	-	-	-	-	-	-	
Total	166680	166719	111187	150259	226851	239089	176798
(Tons/hr)	345	437	312	311	405	470	383
Thickener Input (dry tons/month)							
no.4	826	834	550	742	1120	1170	874
no.5	350	0	319	441	698	517	387
no.3	-	-	-	-	-	-	
Total	1176	834	869	1183	1818	1687	1261
Belt Press Recovery (dry tons/month)							
no.4	785	792	522	705	1064	1112	830
no.5	332		303	419	663	491	368
no.3	-	-	-	-	-	-	
Total	1117	792	825	1124	1727	1602	1198
(Tons/hour)	2.45	2.20	2.46	2.47	3.27	3.34	2.75
Total Product Sales at $36/Ton,($/month)	40225	28509	29705	40466	62186	57682	43129
Operating and Maintenance Cost ($/month)							
Operating Labor (1 shift/wk)							
Days Operating/Month	19	15	14	19	22	20	18
Days Worked / Month	4	3	3	4	4	4	4
Hours Worked / Month	30	24	22	30	35	32	29
Total Operating Labor(17.50/hr),($/month)	532	420	392	532	616	560	509
Operating Expenses							
Process Chemicals ($/month)	11888	9385	8760	11888	13765	12514	11367
Electric Power(.05/kwh) ($/month)	1079	852	795	1079	1249	1135	1031
Maintenance ($/month)	2100	2100	2100	2100	2100	2100	2100
Total Operating & Maintenance ($/month)	15599	12757	12046	15599	17730	16309	15007
Gross Incremental Income ($/month)	24626	15752	17658	24868	44456	41373	28122
Total Equipment & Installation Cost ($)	339003	339003	339003	339003	339003	339003	339003
Engineering Cost ($)	67801	67801	67801	67801	67801	67801	67801
Margin ($)	81361	81361	81361	81361	81361	81361	81361
Total Installed Cost ($)	488164	488164	488164	488164	488164	488164	488164
Simple Payback (years)	1.7	2.6	2.3	1.6	0.9	1.0	1.4
Coal Recovery (%)	0.7	0.5	0.7	0.7	0.8	0.7	0.7

* The flows are as measured and reported
** 1 metric ton at 1.1 ton

4. DISCUSSION OF HARDWARE

4.1 Operation of Thickener/Belt Press

A schematic of the Parkson belt press is shown in Figure 2.11. Its principle of operation is to initially combine the feed, containing 15% solids, with approximately 1–1.5 kilograms (2-3 lb) of flocculant per ton of dry coal. This mixture is introduced to a rotating flocculating/dewatering drum, where the rotational motion serves to provide increased contact time for the flocculating mixture, as well as provide mechanical flocculation. Some gravity dewatering occurs in this drum, initiating the concentrating process.

Following the dewatering drum, the mixture is spread on a moving, seamless belt, and allowed to drain under the effects of gravity. Motion of the belt brings it to the gradual squeeze zone, where a second continuous belt is brought to bear against the dewatering mixture. The high-pressure multi-roll pressure/shear zone is next, where the desired degree of dewatering is reached. Finally, the dewatered product exits the press, and is doctored off of the two belts.

The belt press is in series with the existing 18.3 meter (60 foot) thickener. Figure 4.1 illustrates the final equipment arrangement. Underflow from the existing thickener will be transferred via diaphragm pumps to the belt press, or bypassed back to the inlet of the thickener. This equipment arrangement:

- Maximizes control of thickener underflow density.
- Minimizes degradation of floc structure.
- Minimizes plug-ups and other maintenance problems.

Improved-clarity overflow water is removed from the first thickener and used for scrubbing the thermal dryer exhaust gases. Concentrated product CWM is removed as underflow from the thickener/belt press and used for de-dusting the thermal dryer product coal.

4.2 Control of Thickener/Belt Press

Providing automatic control of the thickener system is critical to successfully control the thickener/belt press process. In particular, it is necessary to maintain a constant feed rate to the thickener, as well as to maintain a constant underflow loading from the thickener, which will produce a constant feed for the belt press. A constant feed rate to the thickener is required for proper operation to produce consistent concentrated CWM from the thickener for de-dusting operations. At JWRI Mine Number 4, the existing 18.3 meter (60 foot) thickener serves as the holding tank for the wet scrubber. Consequently, the flow of feed to the scrubber is metered by the 3920 lpm (1300 gpm) scrubbing fluid pump, ensuring that a constant flow of scrubbing liquor is returned to the first-stage thickener.

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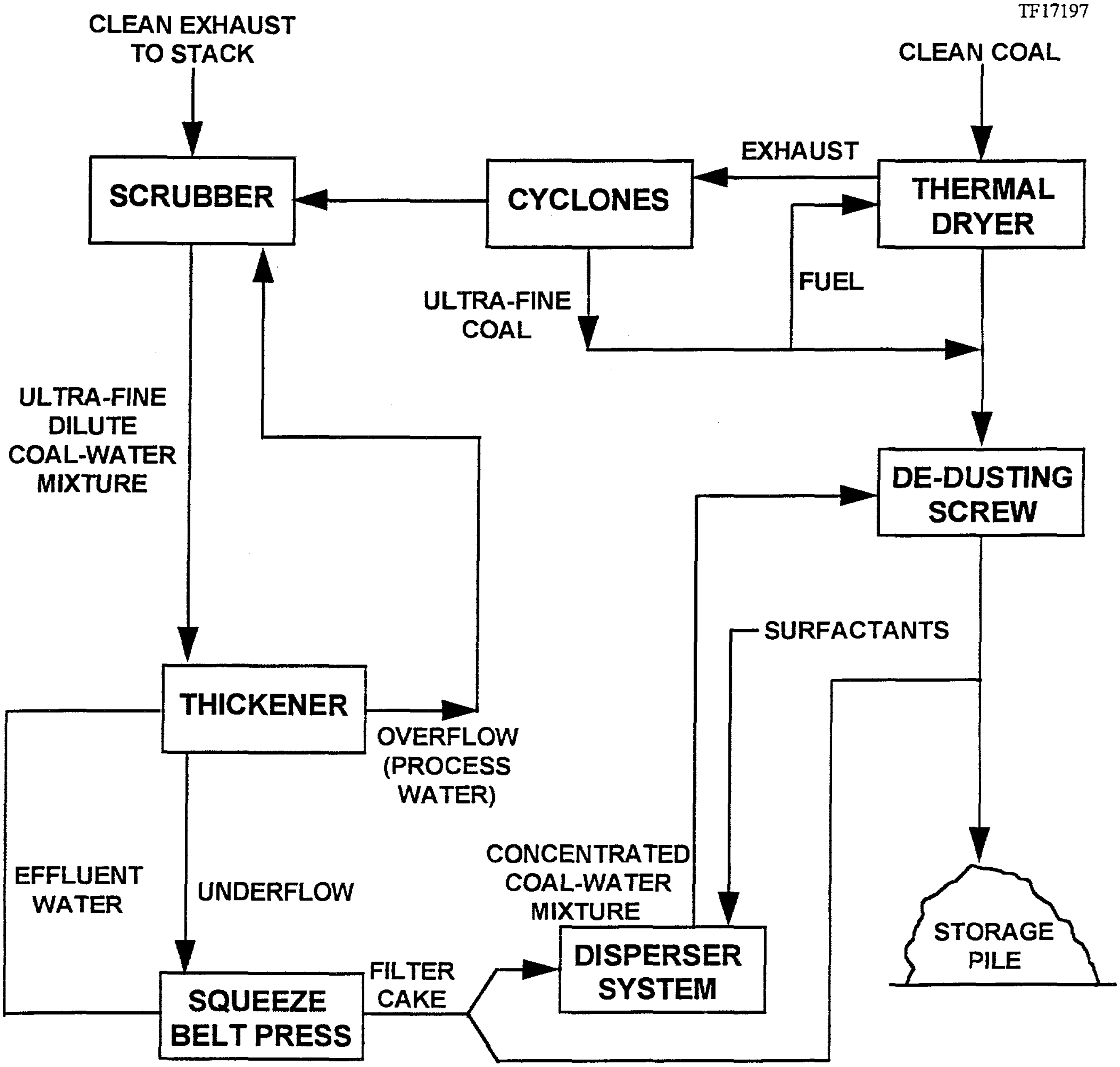


Figure 4.1 Belt Press Integrated to Thickener Underflow Stream

Normal operation of Mine Number 4 will produce occasional variations in the amount of fine coal being removed by the wet scrubber. Consequently, as the inlet feed solids loading varies:

- The bypass of underflow back to the inlet of the thickener tank is varied
- The transfer rate for underflow and overflow circulation between the pieces of equipment is varied
- The flow of product CWM from the belt press system is varied.

For example, the underflow pumping rate from the recirculation loop in the thickener must be increased when an increased flow of solids reaches its bottom outlet. Simultaneously, in order to maintain the water level in the thickener, the combined rate of returning expressed water from the belt press and other sources to the thickener must be increased. A holding tank is provided with sufficient surge capacity to hold the eventual increase in concentrated CWM product from the belt press, evening-out the expected variation in product flow rate. When the solids loading in the feed to the thickener returns to normal, both the inter-unit transfer rate and the concentrated product flow rate are eventually reduced back to normal.

Proper sensor selection for controlling such a units-in-series configuration is important, in order to enable reliable performance to be achieved. Tecogen has identified and used sensors that are ideal for such service. In particular, combined Coriolis mass flowmeter and density sensors are commercially available, which have proven capable of service in a wide variety of conditions. These Coriolis sensors are comprised of one or two bent, vibrating flow tubes, through which a fluid is passed. Electromagnetic velocity sensors are attached to the tube(s). The measured velocity of sensor tube twist caused by the flowing fluid's Coriolis force is directly proportional to the mass flow rate through the tube(s). Similarly, the density of the fluid is determined by measuring changes in the resonant vibration frequency of the flow tube(s).

Several such Coriolis sensors will be used in the proposed POC demonstration system. One will be used to meter the dilute feed mixture to the thickener, one will be used to measure the underflow product from the thickener, a third will be used to monitor the product CWM, and the fourth will meter the clear expressed water flow being recycled from the belt press to the thickener. Associated standard thickener/belt press control elements and controllers will be supplied to complete the control system. This control strategy will assure satisfactory operation of the thickener/belt-press system, and thereby produce consistent product CWM for the de-dusting operation.

Shutting down a thickener for extended periods is usually preceded by operating the unit until the underflow becomes thin, and settling is complete. This procedure eliminates the maintenance risk of producing a hard-packed layer of product in the bottom of the thickener. With such a shut-down procedure, it is not necessary to operate the thickener during extended shutdown periods, continuously pumping and recirculating underflow. A similar procedure will then continue in the belt press, with it continuing in operation until all solids have passed through the system.

4.3 Engineering Design

The first engineering effort was to analyze the thermal dryer circuit at Mine Number 4. A mass balance of the thermal dryer was prepared by acquiring samples and confirming flow rates throughout the dryer system. A mass balance was then prepared to determine the flow of fine coal into the clarifier. The flow specification chart, Table 4-1, provides pump rates and percent solids needed for sizing all equipment.

The second effort was to integrate the belt press system into the existing thermal dryer. Selecting piping tie-in points and equipment locations within the thermal dryer allowed simplification of the system. Much effort was placed here to fully integrate the belt press into the thermal dryer. Location of the structural steel and belt press discharge were critical to the operation of the press.

The third effort was to create the Piping and Instrumentation Diagram, P&ID. This design map, Figure 4.2, was the focus for the entire design. From the P&ID, all equipment, piping, valves, and instrumentation were identified for procurement.

The fourth effort was designing the control system. Electrical schematics were prepared utilizing the P&ID. A PLC was then programmed to operate the entire system. Programming efforts included auto start/stop, auto water purge of slurry lines, auto ramping up and down of underflow pump speed, auto ramping of belt press speed, auto ramping of polymer injection pumps, and auto operation of slurry de-dusting equipment. An operator interface terminal (OIT) with a 40 character display is used to operate the system. Operation of the press system can be performed from two locations, within the belt press room or in the main dryer control room.

4.4 Installation and Start-up

Integration of the belt press system into the existing thermal dryer was the most time consuming of all the technical tasks. Much effort was put into satisfying JWR's needs for the belt press system and to complete all DOE system requirements. JWR required the option of discharging the belt press output directly onto the dryer main product conveyor in addition to the project requirement to make slurry for de-dusting. This added complexity created the need for a diverter chute. The diverter chute redirects the discharge of the belt press from the dryer conveyor to the dispersal slurry tank, Figure 4.3. This added requirement also determined the belt press location within the thermal dryer, Figures 4.4 and 4.5. Structural integration with the existing thermal dryer structure created the need for new column footings. Equipment layout followed the belt press positioning, Figure 4.6. The belt press subsystem (pumps, compressor, flocculant station, etc.) determined the electrical installation. Electrical requirements, Table 4.2, allowed the sizing of wire, conduit, and circuit loads. Structure lighting and convenience outlets were added, all of water tight construction. Completed mechanical and wiring installation drawings (see appendix A2 and A3) were supplied to contractors for bidding. Actual site photos were taken to show construction progress (see Appendix A4).

Once installation was completed, the shakedown and start-up process was begun. Shakedown was fairly routine. All electrical systems were tied into the PLC. Operation of each component was confirmed with the use of a portable computer linked to the PLC. Small wiring errors and mechanical imperfections were found and corrected during shakedown.

Start-up proved to be equally as routine. Programming changes of constants and system timers allowed for smooth operation. Some reprogramming of the PLC, due to system constraints, was necessary.

Table 4.1

JWRI Thickener Underflow Conversion
Flow Specifications

POINT	NAME	COAL LOADING (% lbm)	FLOW (gpm)	FLOW (lb/min)	VELOCITY (ft/sec)	SIZE (inches)	SPECIFIC WEIGHT (lb/cu. ft.)
1	Scrubber Return	1.00	1,300.00	10,844.92	15.00	5.95	62.40
2	Thickener Underflow	23.00	52.49	471.52	7.00	1.75	67.20
3	Recirculation	23.00	52.54	471.99	7.00	1.75	67.20
4	Belt Press Inlet	23.00	52.54	471.99	7.00	1.75	67.20
5	Flocc 1820A 1589C	0.10	0.05	0.47	0.31	0.25	74.88
6	Beltpress Outlet	70.00	16.17	155.08	18.84	39.37	71.76
7	Surfactant	0.00	0.06	0.53	6.00	0.06	71.76
8	Dust Suppressant	0.00	2.31	19.26	0.79	1.00	62.40
9	Conveyor Outlet	70.00	16.17	155.08	23.18	10.00	71.76
10	Dilution Water	0.00	6.51	54.28	15.00	0.41	62.40
11	Slurry Flow	50.00	16.97	162.84	7.00	1.03	71.76
12	Cyclone Output	99.15	100.38	963.00	0.41	10.00	71.76
13	Screw Outlet	98.00	118.55	1,137.34	0.48	10.00	71.76
14	Filtrate/Wash Outlet	1.00	138.00	1,151.13	15.00	1.94	62.40
15	Thickener Overflow	1.00	1,247.51	10,407.05	15.00	5.83	62.40
16	Wash Inlet	1.00	100.00	834.22	15.00	1.65	62.40
17	Purge Water	1.00	40.00	333.69	15.00	0.50	62.40
18	Compressed Air	0.00	4.80	0.35	7.84	0.50	0.55
	Dust Screw Percent	10.97	%				
	Coal Recovery	78.16	Ton/day				
		3.26	Ton/hr				

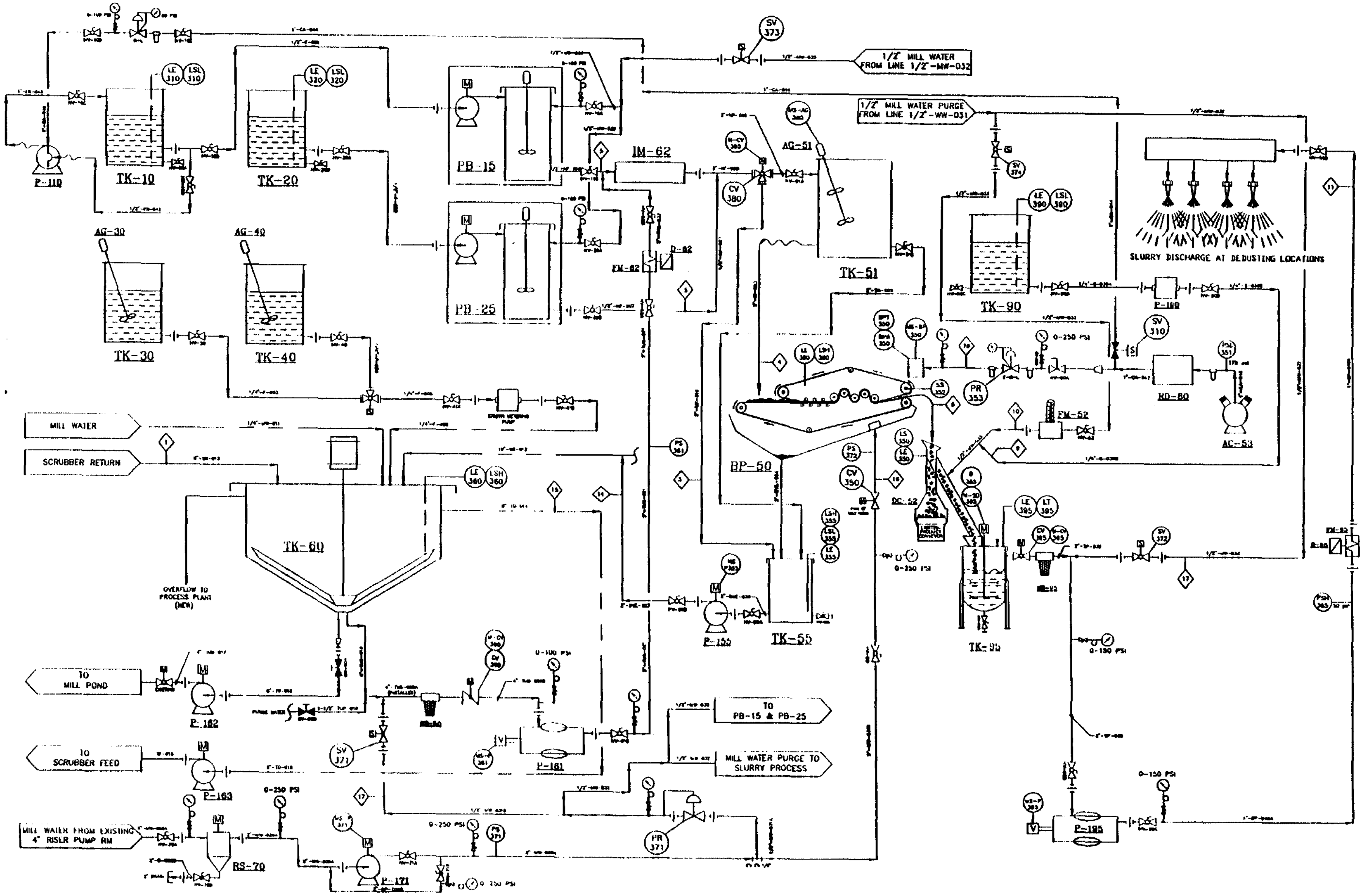


Figure 4.2 Piping and Instrumentation Process Flow Diagram

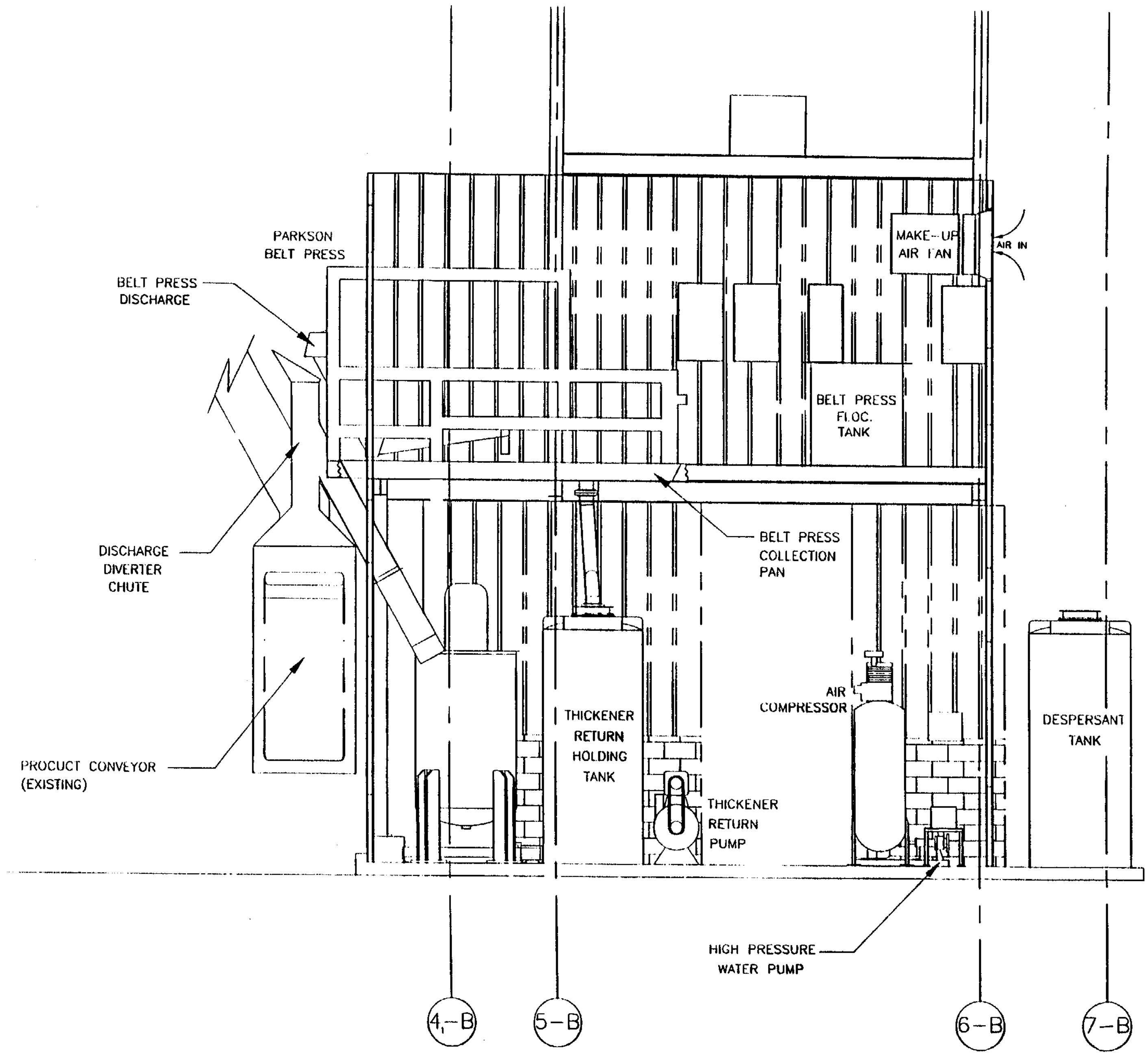


Figure 4.3 Equipment Layout Elevation

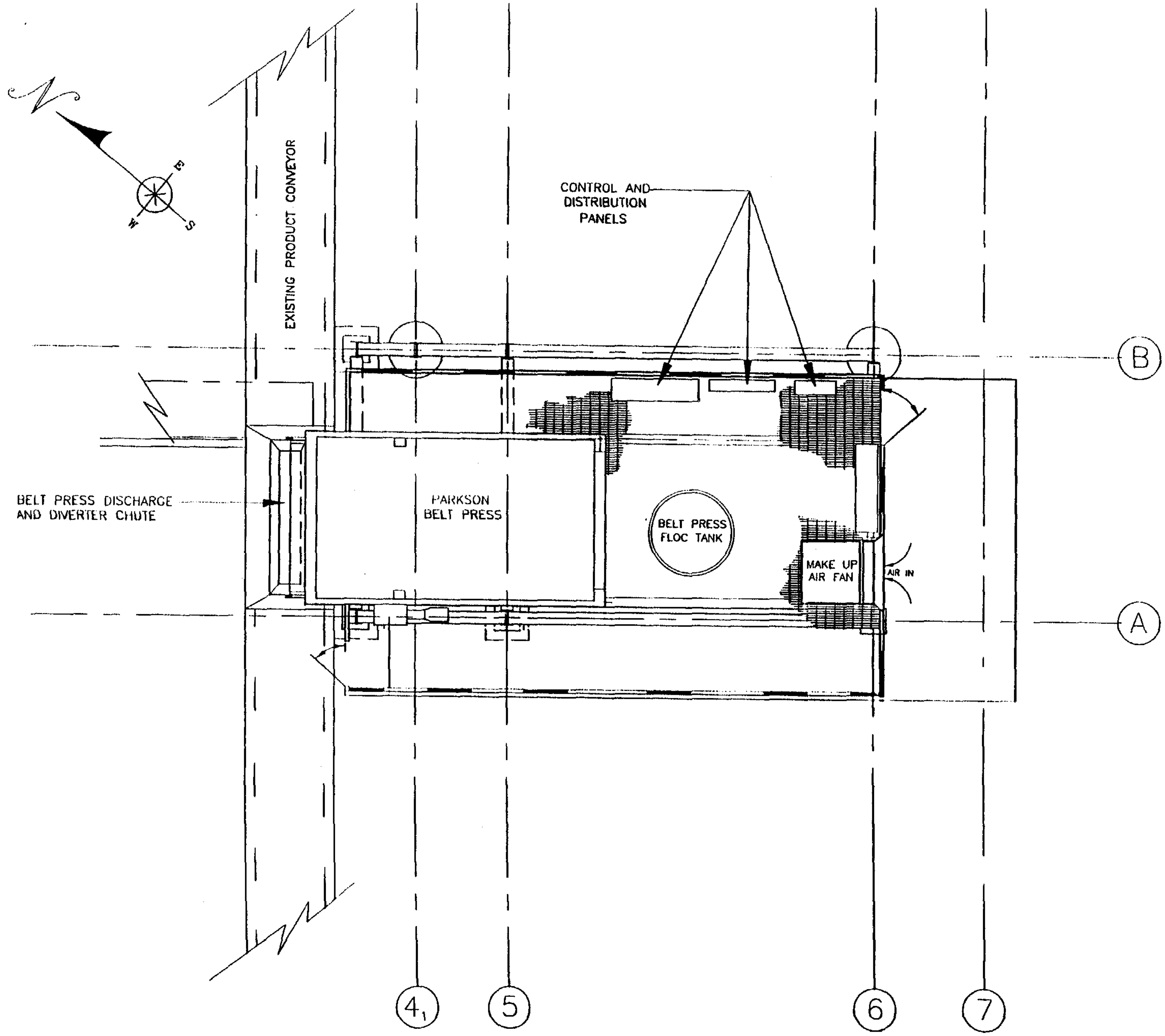


Figure 4.4 Equipment Layout Belt Press Level Plan

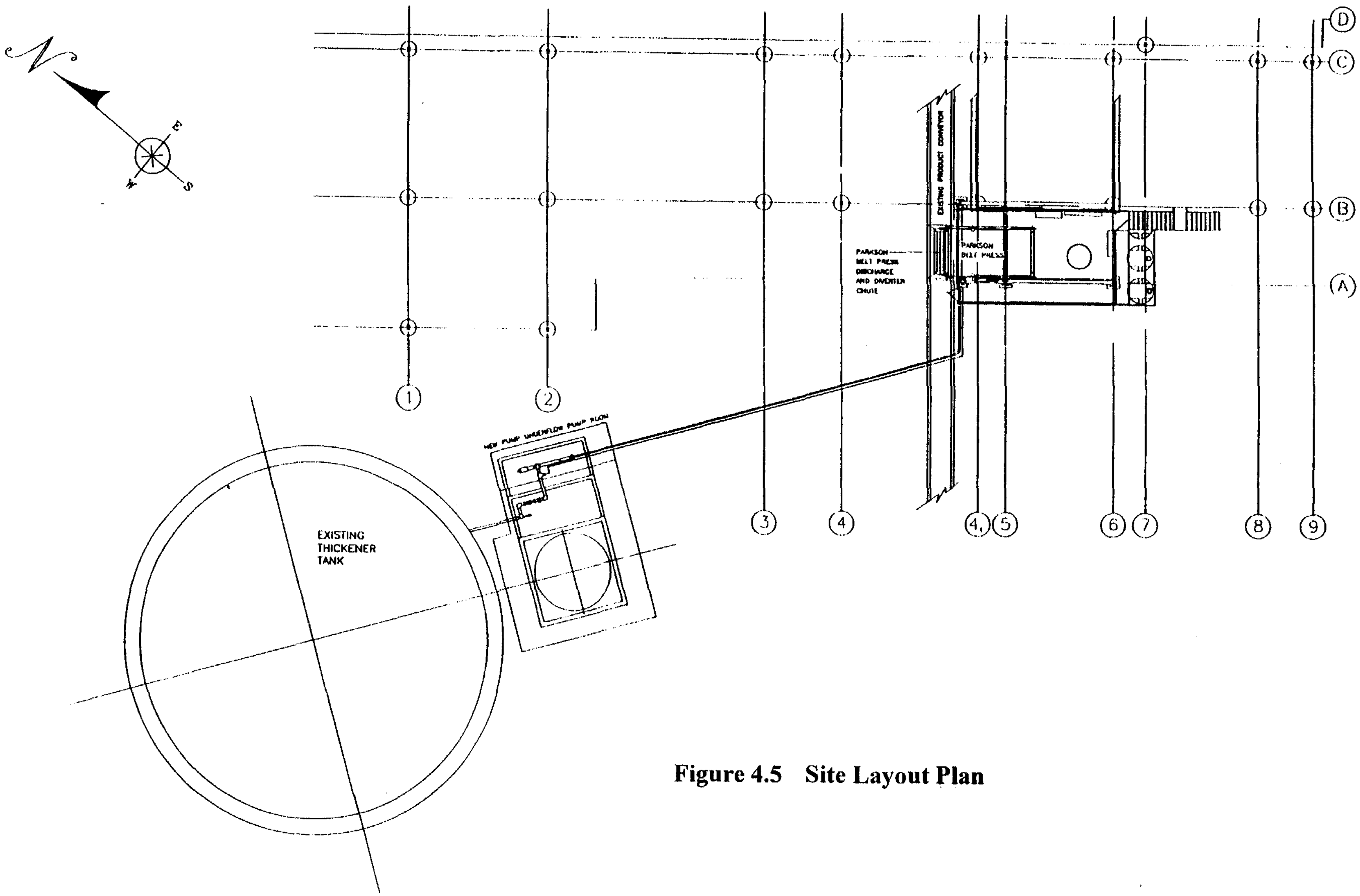


Figure 4.5 Site Layout Plan

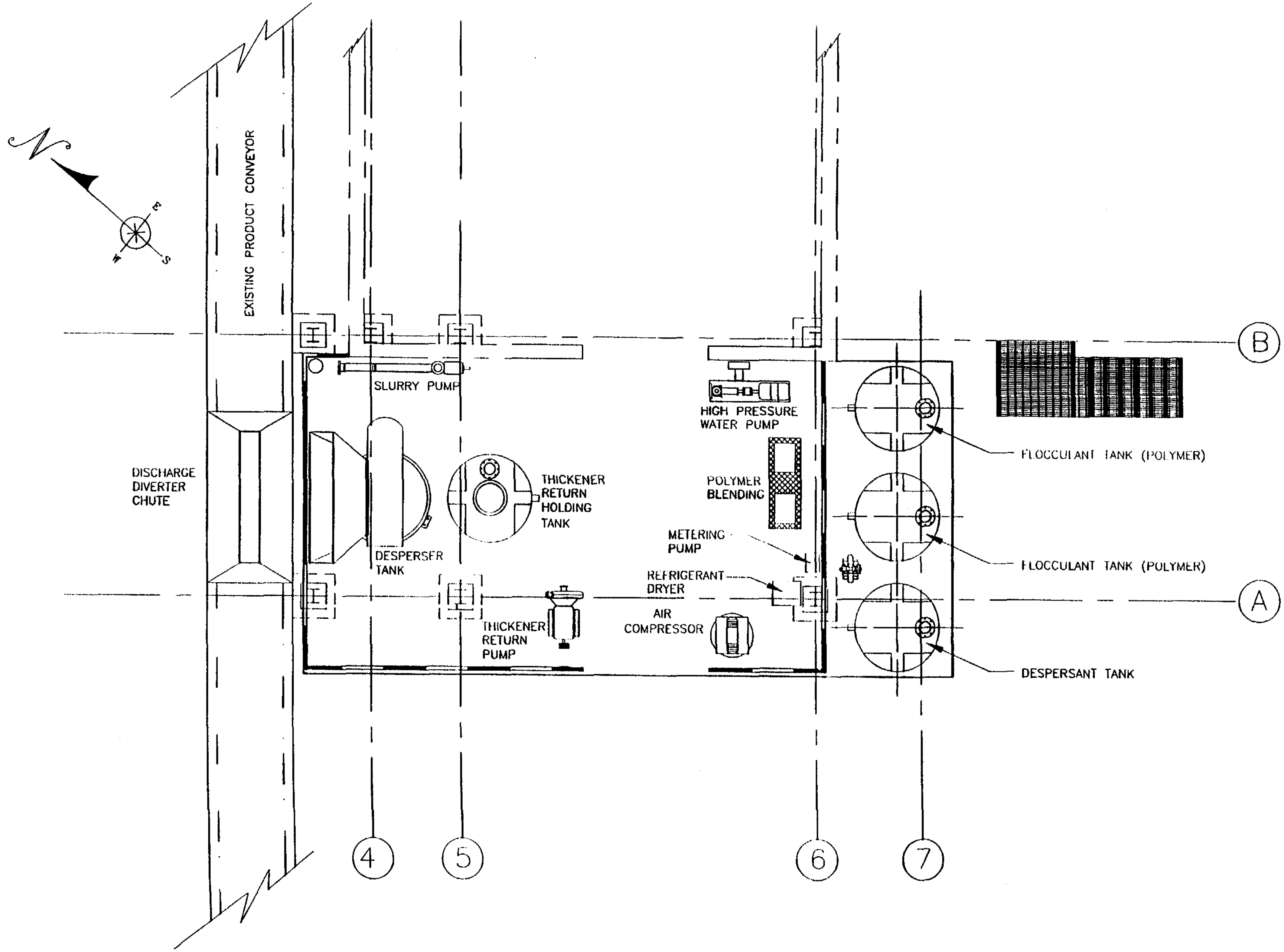


Figure 4.6 Grade Level Equipment Layout Plan

Table 4.2

JWRI Thickener Underflow Conversion

System Power Requirements

DESCRIPTION	HORSEPOWER	VOLTAGE	RPM	AMPS	BREAKER 1.25*
Belt Press Drive	5.0	480	1,800	7.6	15
Belt Press Mixer	0.5	480	1,800	1.0	15
Dispersal	40.0	480	1,800	47.6	70
Underflow Pump	5.0	480	1,800	7.6	15
Water Pump	30.0	480	1,800	40.0	50
Slurry Pump	3.0	480	1,800	4.8	15
Sludge Pump	3.0	480	1,800	4.8	15
Air Compressor	3.0	480	1,800	4.8	15
Control Panel		110		10.0	
Flocc System		110		10.0	
TOTAL 3 PHASE	89.5	460		122.6	
TOTAL 1 PHASE		110		20.0	

*Variable Speed

5. EVALUATION OF SLURRY DE-DUSTING CAPABILITY

In addition to recovery of the fine coal by the use of a belt press, it was speculated that the slurry suspension chemicals might exhibit the same dedusting qualities as the surfactants often used for this purpose at coal mines. To test and verify this assumption, slurry formulation equipment was incorporated into the fine coal recovery loop as shown and discussed in Chapter 4. Prior to investing both labor and time into this potential technology, laboratory tests were conducted. The results of the laboratory tests and the field demonstration tests are discussed below.

5.1 Laboratory Slurry De-dusting Evaluation

The principal cause of fugitive dust in and around coal dryer facilities is from wind entrainment off of the stacking pile and during the free fall from the stacking cone to the pile. In order to quantify the dedusting ability, it was necessary to develop a methodology to simulate this effect. To do this, we developed a wind tunnel test facility to simulate the dust entrainment at various wind velocities. This test facility is show in Figure 5.1.

The facility, as shown, consists of the wind tunnel chamber, the dust sample tray, an air velocity probe, a particulate sample system and an induced draft fan to create the wind. The particulate sample system consists of a barrier filter, a flow meter to run isokinetic samples, and a vacuum pump to provide the suction.

5.1.1 Test Coals

In this work, it was originally anticipated using three coals. The JWRI coal and two other coals, one from the East and one from the West. During the program kick off meeting, it was agreed that sites with dryers would be used to supply these samples and DOE was to provide a list of potential dryer facilities and contact points. As it turned out, the list of coal drying facilities was quite limited with nonoperating outside of Alabama. There are a number of coal cleaning facilities, but the need to thermally dry the coal for boiler fuel does not exist. Therefore, only one Eastern coal was tested, that being the JWRI coal as other coals from Alabama were believed not to be significantly different as to warrant testing.

It was at this point that it was decided that the additional test coals would come from coal processing plants, one in the Midwest and one in the West. Contacts were made with Westech, a sub-bituminus coal dewatering facility in Wyoming, to see what their process was and to determine if our technology, that of dedusting, would be applicable. Westech was responsive to our requests and provided us with both process information and a coal sample. The process is discussed in Chapter 6. With regard to making contacts with the Illinois coal processing facilities, several attempts were made with no success. The last attempt was made in June 1996 to investigate whether we could get a sample of processed coal through our contacts at Southern Illinois University. These also fell short, and subsequently, only two coals were tested, the JWRI coal and the Westech coal.

5.1.2 Laboratory Tests

Two different coal samples were obtained from JWRI, these are identified as coal #1 and coal #2. For each of these coals, two baseline wind tunnel tests were run to determine the degree of repeatability and to identify the magnitude of the change needed to access the impact of the test. The two test runs on coal #1 are shown in Figure 5.2. The error bars through the data points define ± 10% values. At wind velocities below 6.1 m/s (20 ft/s) the dust levels from the two tests are very close. Above 6/1m/s (20 ft/s), the dust levels vary by as much as 30%. Figure 5.3 shows the dust levels for all four baseline coal tests, two for each coal, and compares these values to the average value. In this figure, the data appears as single points and the average with error bars of ± 20%.

The effect of slurry dedusting as compared to the JWRI normally used suppressant was tested at low moisture levels, up to 3%. In this comparison (Figure 5.4), two tests with slurry and two tests with the suppressant are compared to the average base line coal as defined above. Basically, it can be stated that for low moisture levels, significant difference could be seen between the baseline coal and using the slurry or the suppressant for dedusting. One point to note, however, is that the use of the slurry possibly increased the dust level in the intermediate velocity range of 7.6 m/s (20) to 7.6 m/s (25 ft/s). A possible cause to this is the fines added from the slurry.

To explore this observation, a test with water was conducted and compared to the slurry and suppressant dedusting results. The use of water alone as a dedusting agent worked as good as the suppressant. This data is shown in Figure 5.5.

Noting that the effect of water alone had a positive effect on the dedusting process, it was postulated that if the moisture level was increased high enough with the addition of the slurry, the moisture level might compensate for the increase in fines and dusting potential. Therefore, a series of tests were conducted using slurry as the dedusting medium at moisture levels up to 14%. This data is shown in Figure 5.6. At moisture levels of 5.8, a positive effect was starting to be observed. At 6% and higher, the dedusting ability was demonstrated to be very good.

The other coal tested was the Westech coal. Figure 5.7 shows the repeatability and defines the average for this coal. The error bars were defined at ± 6%. Figure 5.8 shows the effect of adding slurry for the dedusting agent on this coal. With this coal, the more slurry added, the greater the dust potential. As the trend was increasing, additional tests were not conducted.

5.2 Field Slurry De-dusting Evaluation at JWRI

The slurry dedusting was tested in the field in a series of tests. To begin this effort, a batch of 40% solids slurry was manufactured. The slurry spray was tested by spraying the slurry out onto the coal pile to evaluate spray quality and assess if the nozzle would plug. After this evaluation, the slurry test program was enacted. In this program, the first point was an evaluation of the opacity in the baseline operating mode. The baseline operation consisted of foam suppressant and no filtercake from the press. Under this condition, the opacity above the coal pile was 10 percent.

In order to evaluate the effect of the suppressant, we were able to convince JWRI to stop the flow of the foam suppressant. The result was an opacity of 100%. The results from these tests can be seen in Figure 5.9. The slurry was turned on and set at increasing flow rates to evaluate the dedusting ability. When the slurry flow was increased to 1 l/s (15 gpm), the opacity was within operational limits, 25%. Another test with the addition of both filter cake and 1 l/s (15 gpm) slurry was also conducted. In this test the opacity increased to 40%, likely due to the increase in fines.

5.3 Slurry De-dusting Conclusion

The use of a slurry can control dust at coal dryer facilities. It does take a higher moisture content to achieve the required level of control and if product quality is affected by product moisture this may not be acceptable. Presently, JWRI is operating the facility recovering coal in the form of cake.

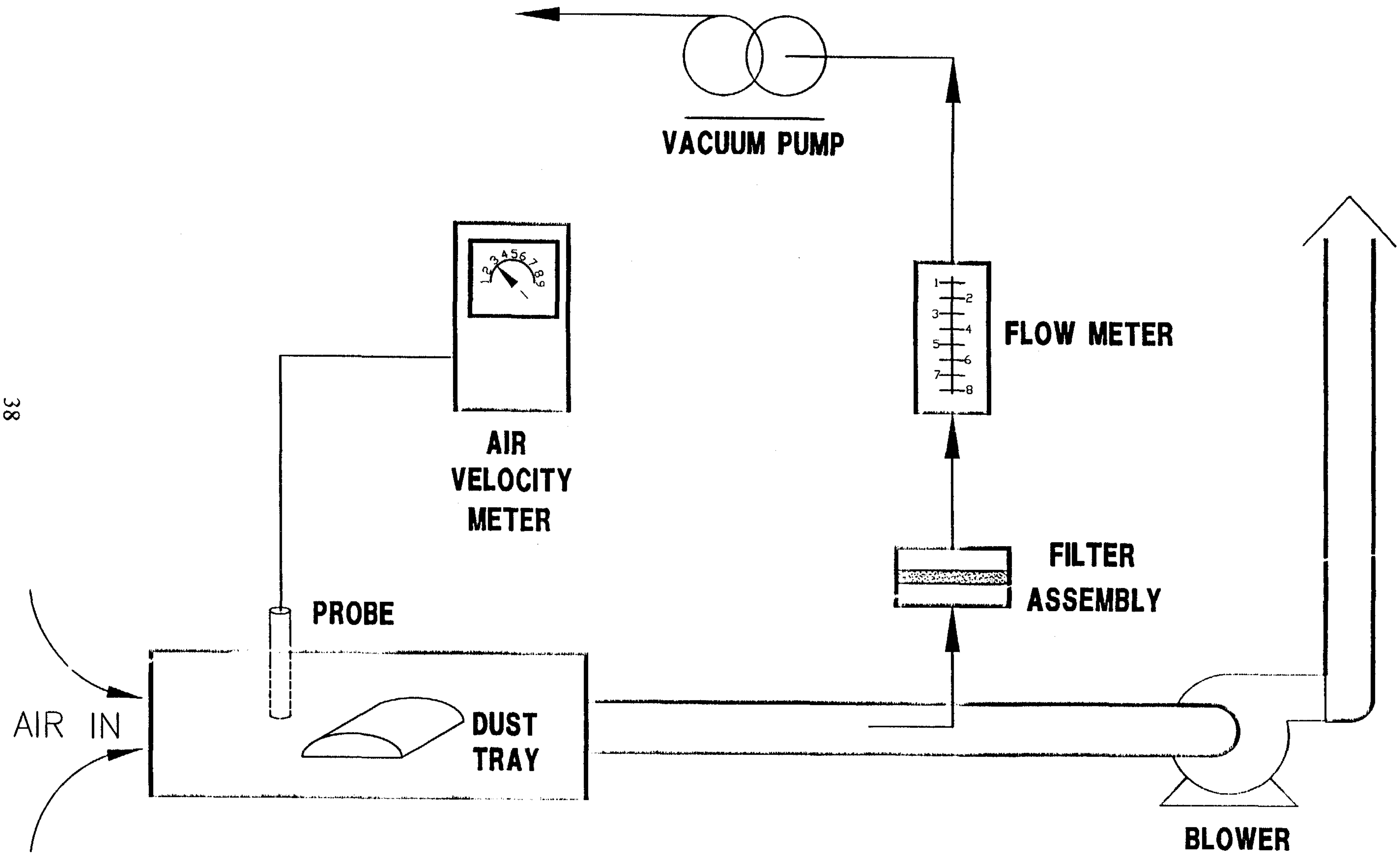


Figure 5.1 Coal Dust Flow Chamber

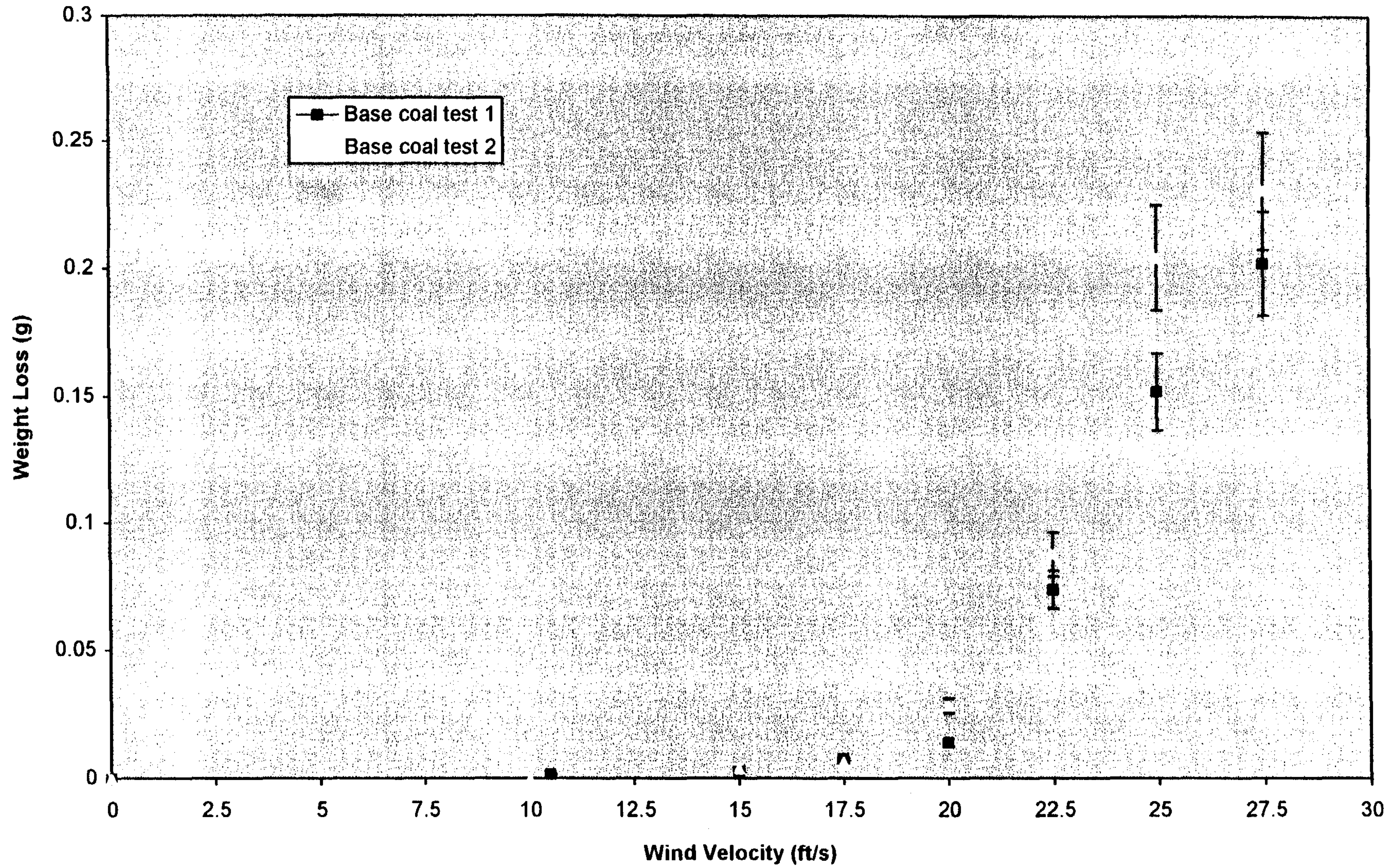


Figure 5.2 JWRI Coal Number 1 - Test Repeatability

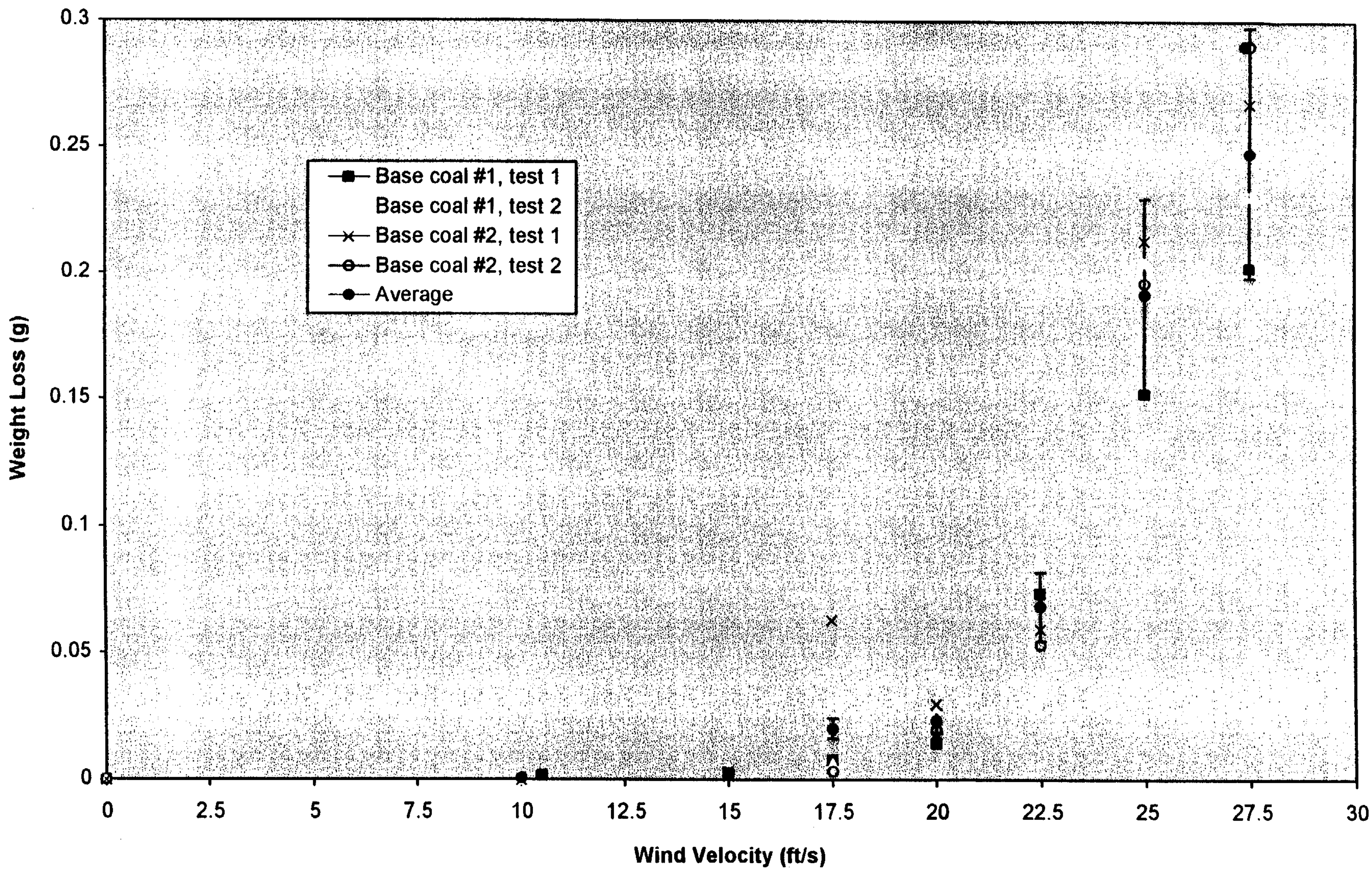


Figure 5.3 JWRI Coal Numbers 1 & 2 - Test Repeatability

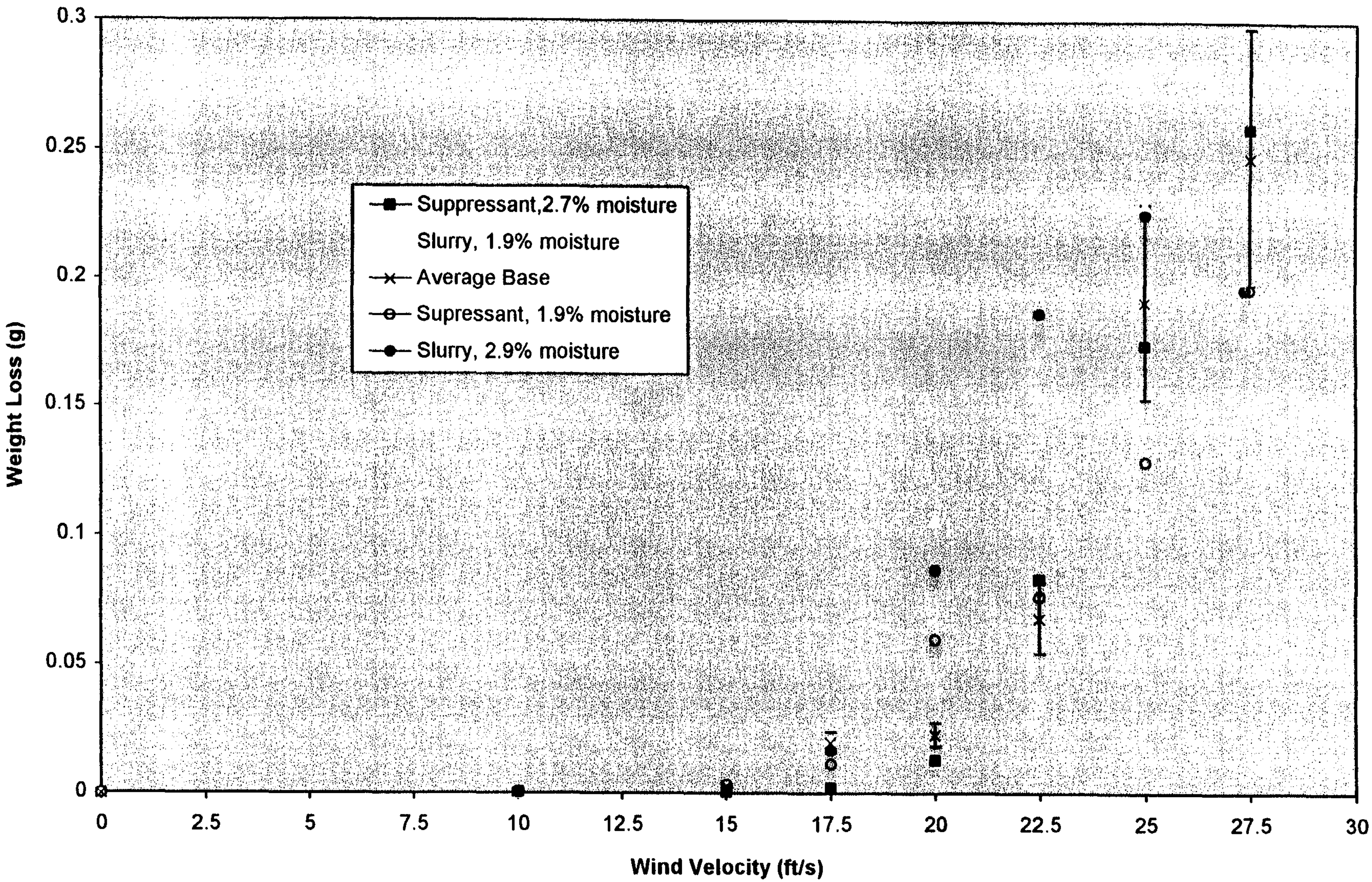


Figure 5.4 JWRI Coal - Slurry and Suppressant - Effectiveness of Low Moisture

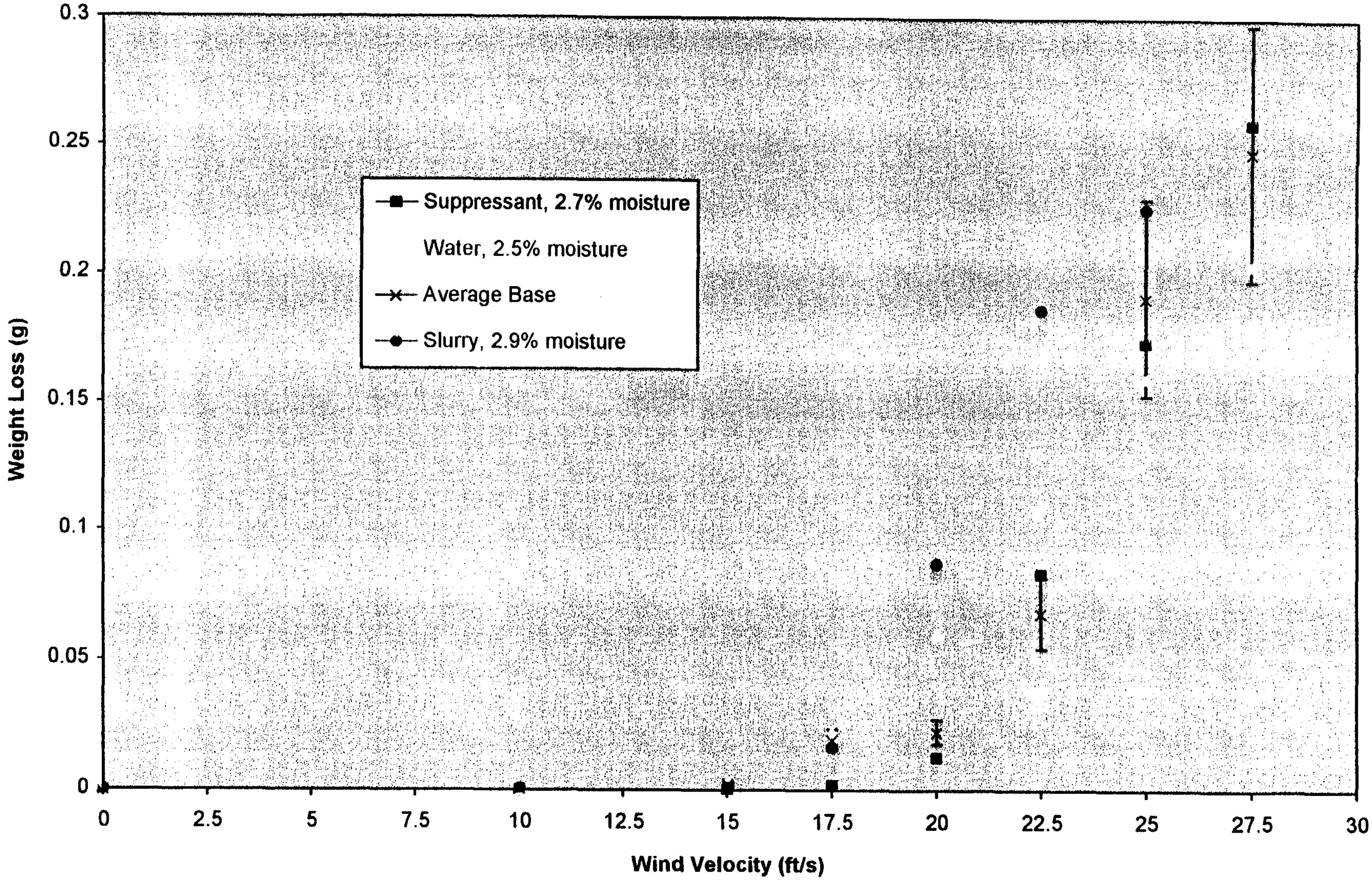


Figure 5.5 JWRI Coal - Effectiveness of Agent

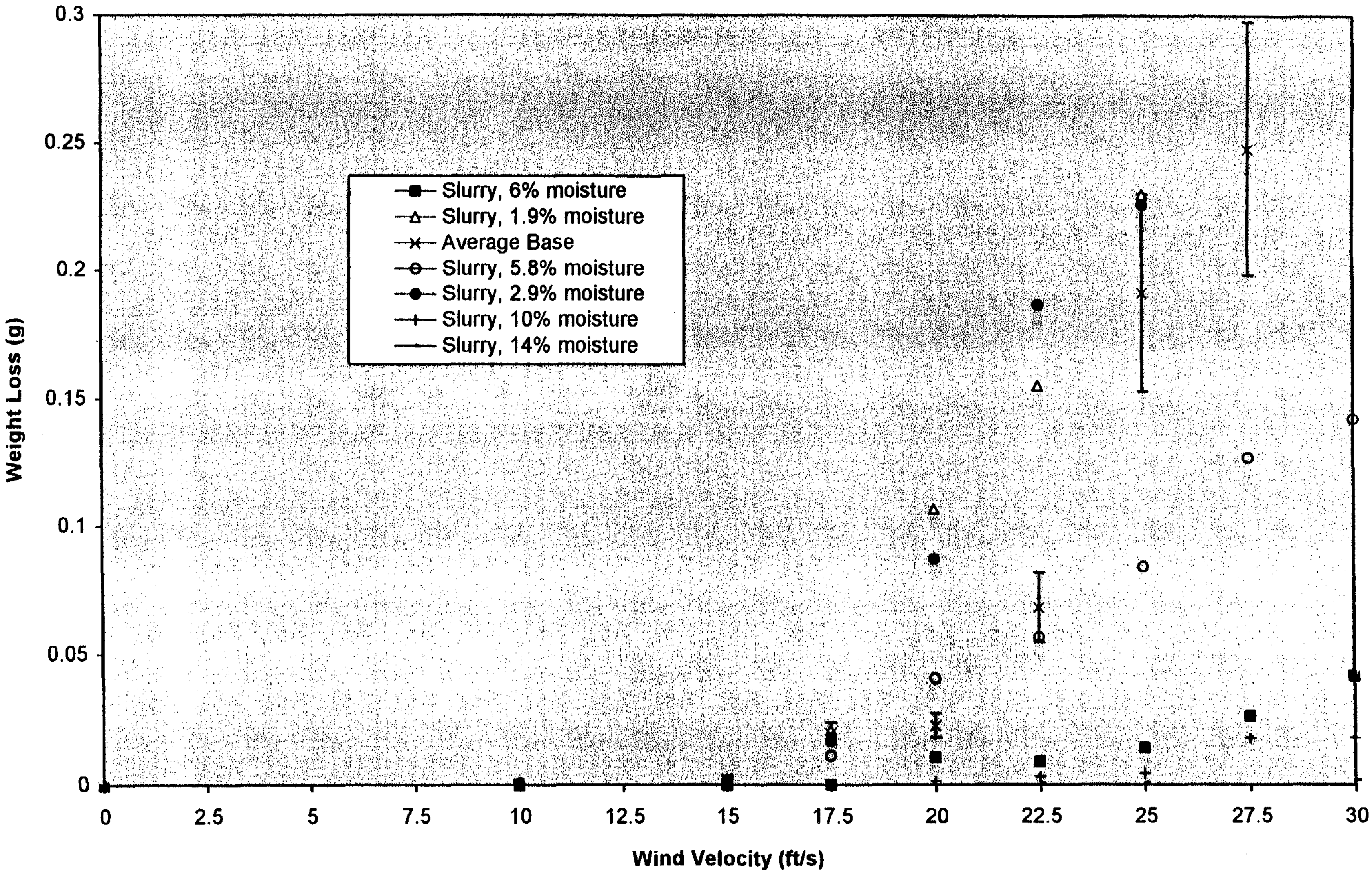


Figure 5.6 JWRI Coal - Slurry - Effects of Moisture

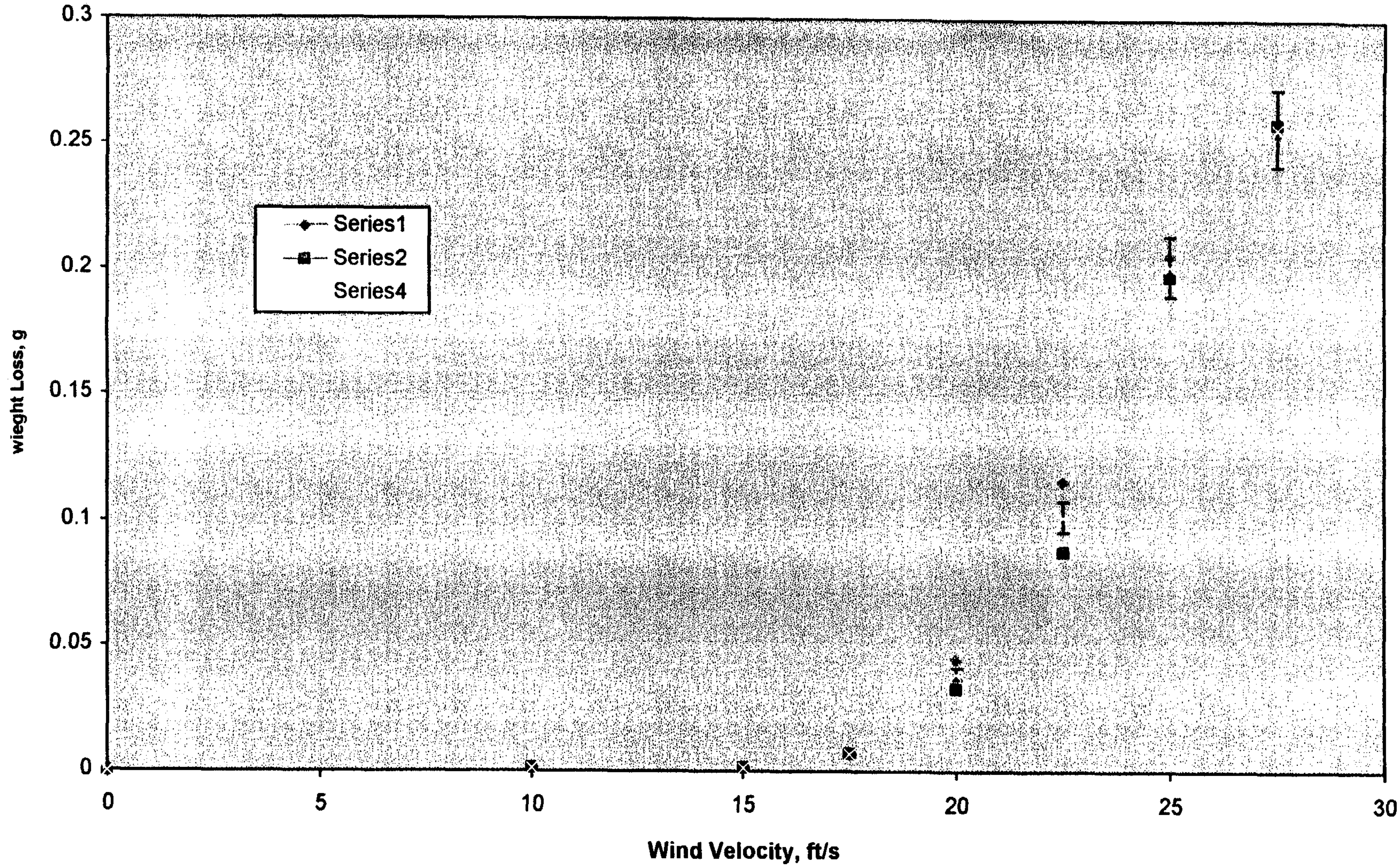


Figure 5.7 De-dusting of Wectech Coal - Repeat Test and Average

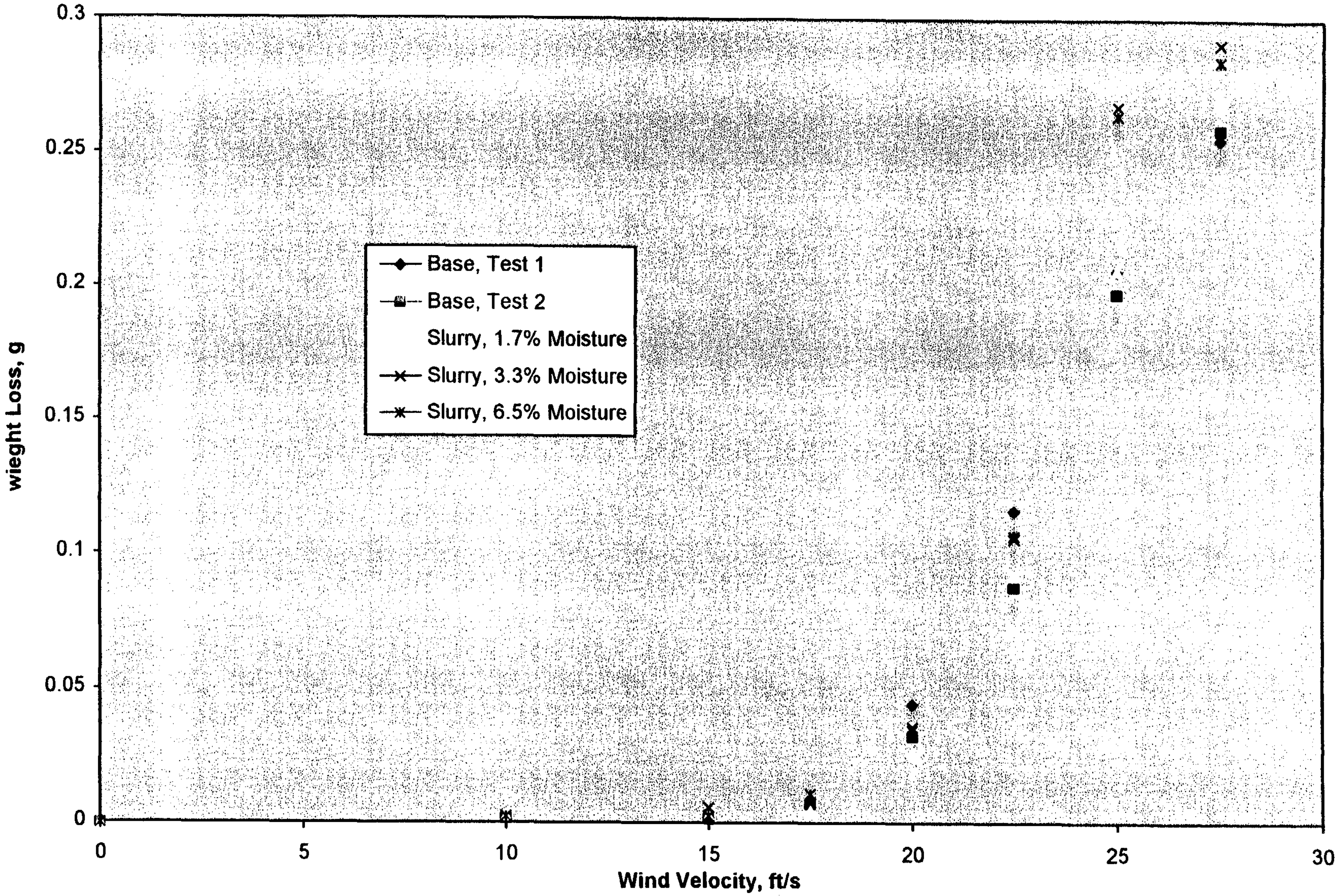


Figure 5.8 De-dusting of Wectech Coal

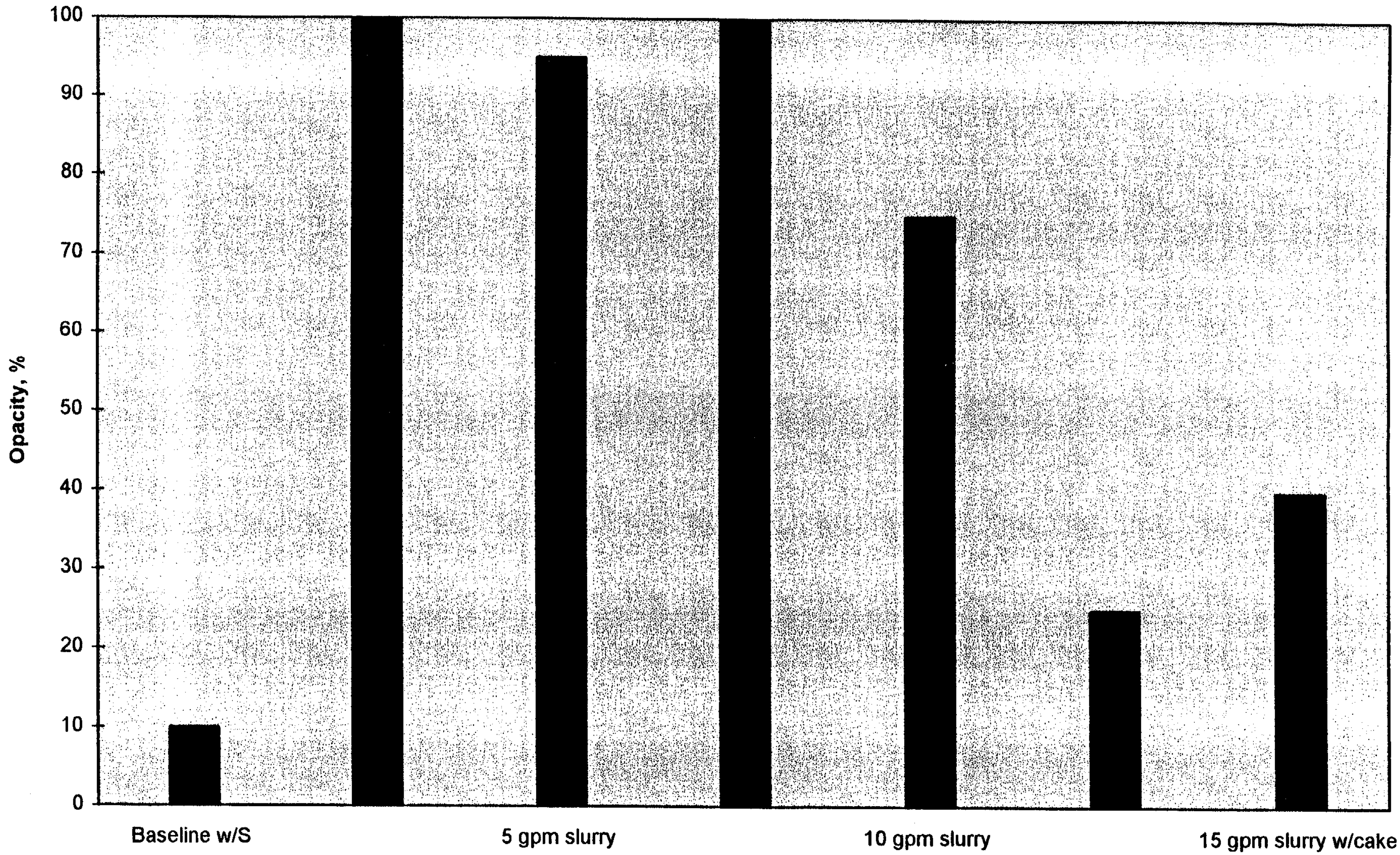


Figure 5.9 Operational Data on Slurry De-dusting

6. SYSTEM ECONOMICS

6.1 System Cost Analysis

Modern day coal mining and preparation facilities are capital-intensive. For example, a $750,000,000 capital investment of the JWRI Mining Division is required for the annual production of 9.1 million metric tons (10 million tons) of clean coal. This investment represents an average of $83 for each metric ton/year ($75/short ton/year) of annual coal production. The CWM/de-dusting system cost analysis, summarized in Table 6.1, shows that not only is the proposed system much less capital intensive than JWRI's average investment, but simple payback periods range between approximately one-half to one year.

The full-scale fine coal recovery/de-dusting system requires one 18.3 meter (60 foot) diameter thickener and a single one-meter wide belt press to dewater the 3.6 metric tons (four short tons) of dry coal per hour from thermal dryer scrubber effluent. The installed cost of a typical 3.6 metric ton (four short ton/hour solids recovery) commercial thickener/belt press system is approximately $550,000. Resultant annual bone-dry fine coal recovery of this system is 16,300 metric tons/yr. (18,000 tons/yr), assuming it is installed on a dryer operated on a three-shift/four-day workweek (4500 hours of annual operation) similar to Mine Number 4. Annual revenue derived from using this amount of recovered CWM for de-dusting the over-dry cyclone fines, at current rates of $40.79/metric ton ($37/ton), is $666,000/year. The thickener/belt press system capital investment represents an average of $34 for each metric tons/yr of annual coal production. These represent conservative annual revenue and capital investment figures; a 78% improvement would occur if a similar unit was operated for four shifts or 8000 hours/year.

Currently, JWRI pays $3.31 per metric ton to "muck out" their settling ponds. Consequently, there will be a $54,000/year reduction in this tailings disposal cost due to the 16,300 metric tons/year reduction in fines being sent to the ponds.

The major operating cost for a thickener/belt press involves the polymer flocculants. A maximum of 1.5 kilograms of polymer will be required to flocculate each metric ton of dry coal (3 lb/short ton). Therefore, at an average cost of $6.61/kilogram, annual polymer costs will total $162,000/yr. As no additional manpower needs to be added to operate the automated thickener/belt press system, and utilities costs are minimal, the additional operating costs are assumed to be zero. Maintenance costs have been taken to equal 4% of the installed plant, or $22,000/year.

Subtracting the polymer and maintenance costs from the gross annual revenue results in a net revenue of $536,000/year. Dividing the thickener/belt press' $550,000 installed cost by the $536,000 increase in annual revenue yields a simple payback period of 1.03 years. An even more attractive 0.57-year payback period is possible if the proposed system were installed at a four-shift, rather than at a three-shift plant. Clearly, such a capital investment would interest any coal producer.

Table 6.1

System Cost Analysis

	Three-Shift Plant Similar to JWRI Mine Number 4 (4500 hr/yr Operation)	**Four-Shift Plant Similar to JWRI Mine Number 4 (8000 hr/yr Operation)**
Operating Hours (/year)	4,500	8,000
Dry Solids Recovery (ton (metric)/hr)	3.63	3.63
Thickener/Belt Press Installed Cost	$550,000	$550,000
Dry Solids Recovery (ton (metric)/yr)	16,329	29,030
Relative System Utilization	1	1.78
Revenue From Coal (/ton (metric))	$40.79	$40.79
"Muck-Out" Disposal Charge (/ton (metric))	$3.31	$3.31
Flocculant Requirements (kg/ton coal)	1.500	1.500
Flocculant Cost (/kg)	$6.61	$6.61
Annual Maintenance (% of Installed Cost)	4%	4%
Gross Annual Revenue From Coal (/year)	$666,000	$1,184,000
Reduction in "Muck-Out" Costs	$54,000	$96,000
Annual Polymer Cost (/year)	($162,000)	($288,000)
Annual Maintenance (/year)	($22,000)	($22,000)
Net Revenue From Coal (/year)	$536,000	$970,000
Simple Payback Period (years)	1.03	0.57
Specific Investment ($/ton/yr of Solids)	$33.68	$18.95

6.2 Economic Scale Analyses

A set of economic analyses were conducted to evaluate the economic benefits of recovering fine coal for other types of coal. The first evaluation was performed to determine the economic attractiveness of the Jim Walter Resource application at various scales. The second evaluation was for coal fines recovery using Eastern coal and the third evaluation was for a system using Western coal.

The analyses were performed using conventional scaling factors and by adjusting and substituting the base line cost of equipment used in the demonstration. The baseline system is designed for 15 tons/hour. Scaling was performed for systems producing 5 and 25 tons/hour using the Jim Walter Resources application as the JWRI system was taken to be an exact size plant requiring an average size recovery unit. A similar analysis was performed for an Illinois #6 coal at 5, 15, and 25 tons/hour. An application using a Western sub-bituminous coal was selected to evaluate the applicability of a Western coal application for coal fines recovery. This application was evaluated at 5, 25, and 45 tons/hour. The Western coal size analysis was arrived at through discussions with Westech and probable commercial plant sizes. Equipment cost sealing factors were taken from Ulrich, "A Guide to Chemical Plant Engineers' Design and Economics." The scaling parameters used are presented in Table 6.2.

The eastern coal application selected for evaluation is a coal drying operation very similar to that of the Jim Walter Resources application except that it uses Illinois #6 coal. This application does not currently have a thickener, however, so a thickener will need to be added to the Eastern coal application.

The Western coal application selected for evaluation is a slurry de-dusting subsystem for a system marketed by the Western Syncoal Company. This system processes raw western sub-bituminous coal to dry and clean the coal of ash minerals and pyrite.

As stated, the economic analysis was conducted on three process plants:

- The JWRI Alabama plant, representative of thermal dryer facilities;
- A typical ILL #6 cool cleaning plant; and
- The Western sub-bituminous coal preparation plant typical of sub-bituminous coal drying plants.

The comparitive flow diagrams are shown in Figures 6.1, 6.2, and 6.3. Like equipment was scaled from the JWRI actual cost. New equipment was costed from Ulrich, "A Guide for Chemical Engineer Process Design and Ecnomics, John Wiley, 1989."

A comparison of the relative attractiveness of the coal fines recovery systems using the various coals at a 15 tons/hour scale is shown in Figure 6.4. The Jim Walter Resources application is the most attractive at this scale. The Illinois #6 coal application requires a longer payback period at this scale primarily because it requires a thickener which is a major cost item. Still at the 15 tons/hour scale, the Illinois coal application promises a 6-year payback. The Western coal application showed a 25-year payback at this scale primarily because the fine Western coal is not valued as highly as the Eastern or Southeastern coals.

Table 6.2
Typical Exponents For Equipment Cost As A Function Of Capacity

	Size Range	*Capacity Unit*	*Exponents*
Agitator, turbine	4-40	kW	0.50
Blower, single-stage 14kPa	0.05-0.4	$m^{3/}s$	0.64
Centrifugal pump	10-20	kW	0.50
Compressor, reciprocating	200-3000	kW	0.70
Conveyor, belt	5-20	m^2	0.50
Crusher			
Gyratory	12-50		0.83
Jaw	7.5-25		1.15
Dryer			
Drum	5-40	m^2	0.63
Vacuum shelf	10-100	m^2	0.53
Dust Collector,			
Cloth	0.0001-0.5	$m^{3/}s$	0.68
Cyclone	0.0001-0.33	$m^{3/}s$	0.55
Electrostatic precipitator	0.5-2.0	$m^{3/}s$	0.68
Evaporator, agitated falling—film	3-6	m^2	0.55
Filter, plate and frame	1-60	m^2	0.58
Heat exchanger, shell and tube	5-50	m^2	0.41
Kettle, glass-lined, jacketed	3-10	m^3	0.65
Motor, 440 v, totally enclosed	0.75-15	kW	0.59
Refrigeration unit	25-14,000	kW	0.72
Screen, vibrating, single-deck	3-5	m^2	0.65
Stack	6-50	m	1.00
Tank			
API, storage	1000-40,000	m^3	.80
Vertical	0.75-40	m^3	0.52
Horizontal	5-20	m^3	0.60
Tower, process	10-60	m^3	0.60

Figures 6.5, 6.6, and 6.7 describe the total capital costs, operating and maintenance costs, and the payback periods of Jim Walter Resources type of projects at scales of 5, 15, and 25 tons/day. Figure 6.7 shows the effect on the payback period of the value of the recovered coal. As is expected, the recovery of coal in the southeast is strongly affected by the size of the operation and the cost of the coal.

Figures 6.8 and 6.9 display the effect of capital cost and operating and maintenance costs on the results of the payback analysis. Payback will be strongly affected by the capital cost and only slightly affected by the operating and maintenance costs.

Figures 6.10 through 6.15 display the capital costs, operating and maintenance costs, and the payback periods to be expected for fine coal recovery with Eastern and Western coals. Eastern coal applications look quite attractive. Western coal applications are not as attractive primarily because of the low value of fine western coal.

TF96-992

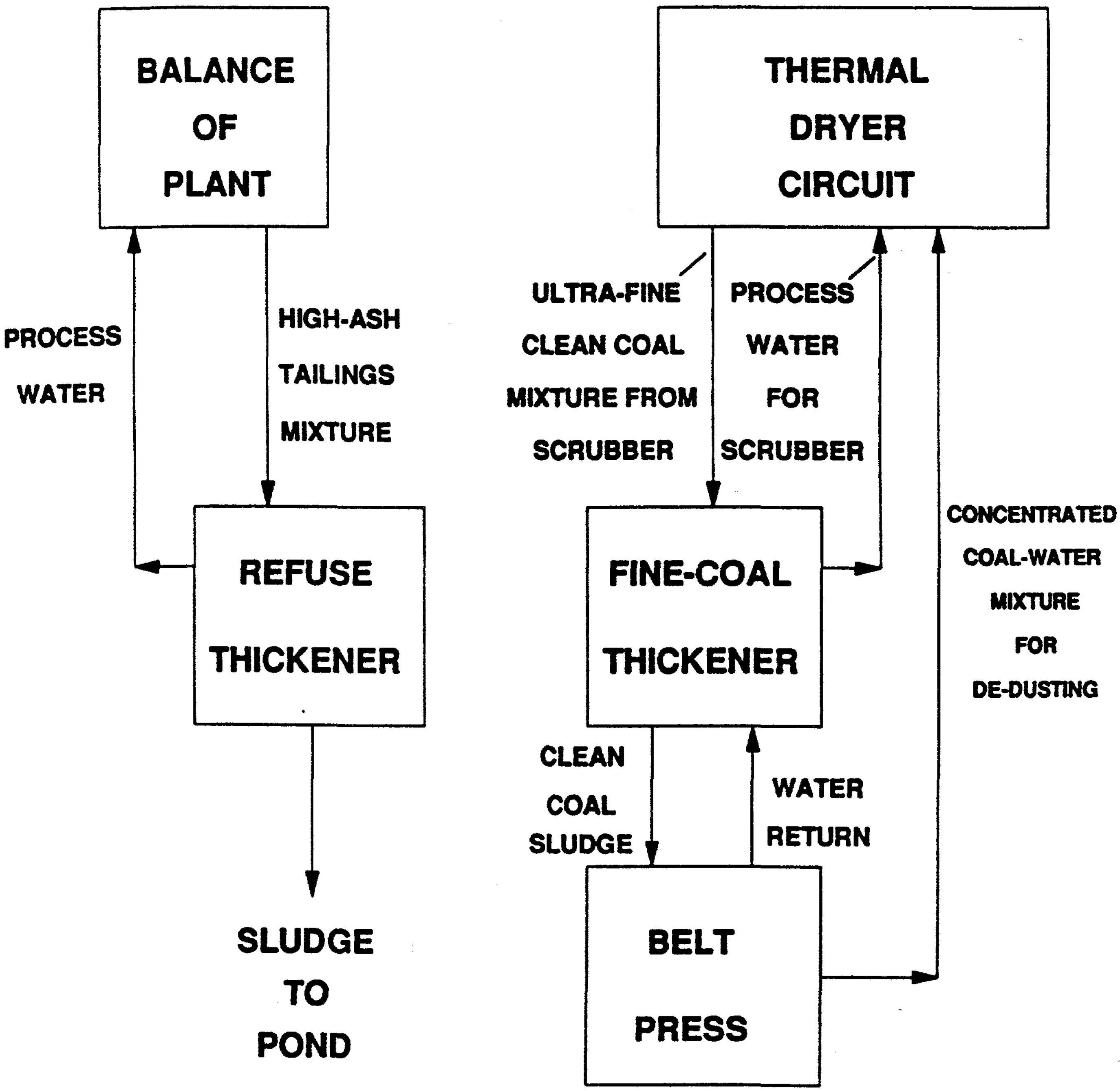


Figure 6.1 Proposed Fine Circuit Modification

TF0212096

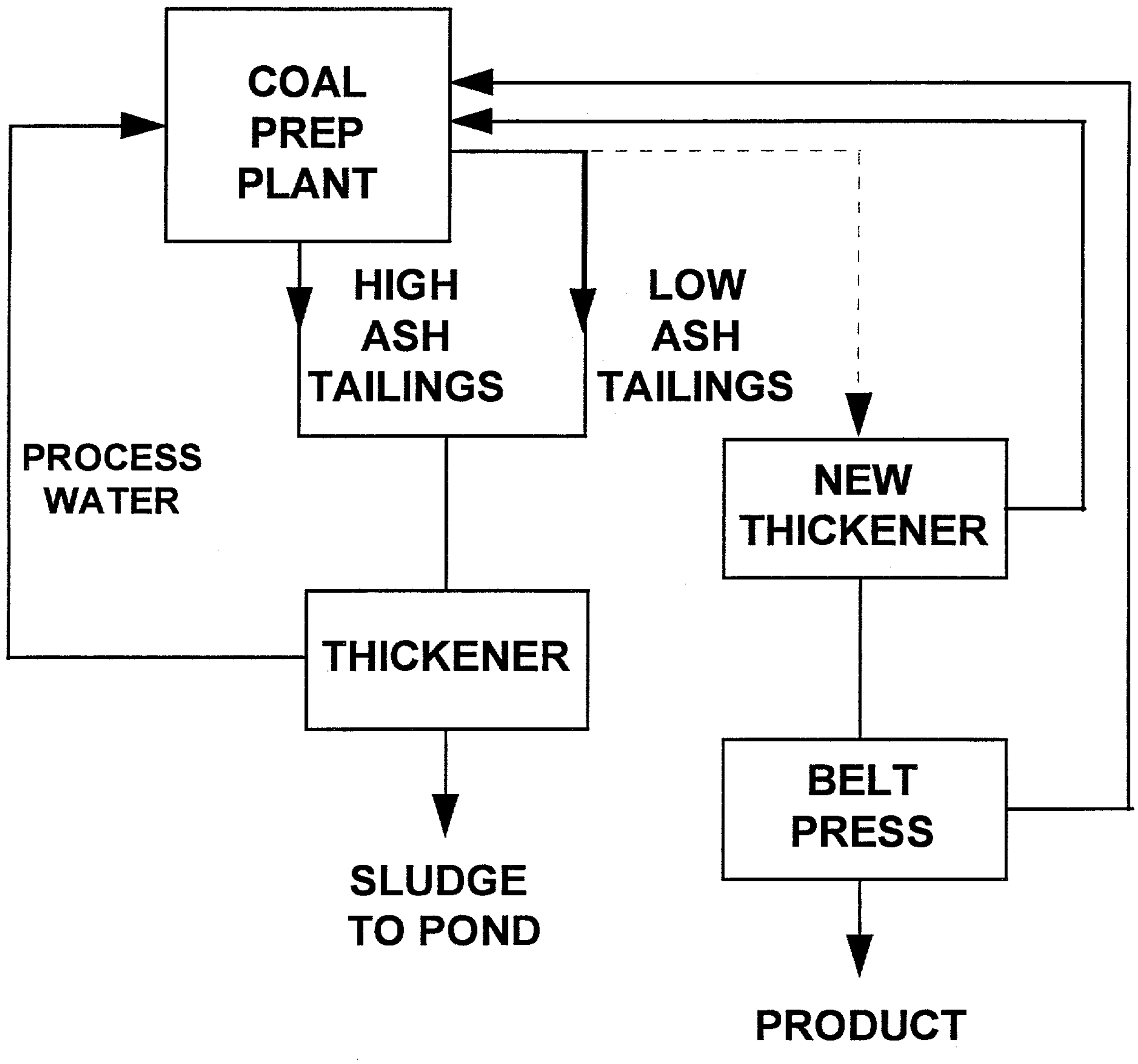


Figure 6.2 Illinois Coal Preparation Plant Circuit

TF03196

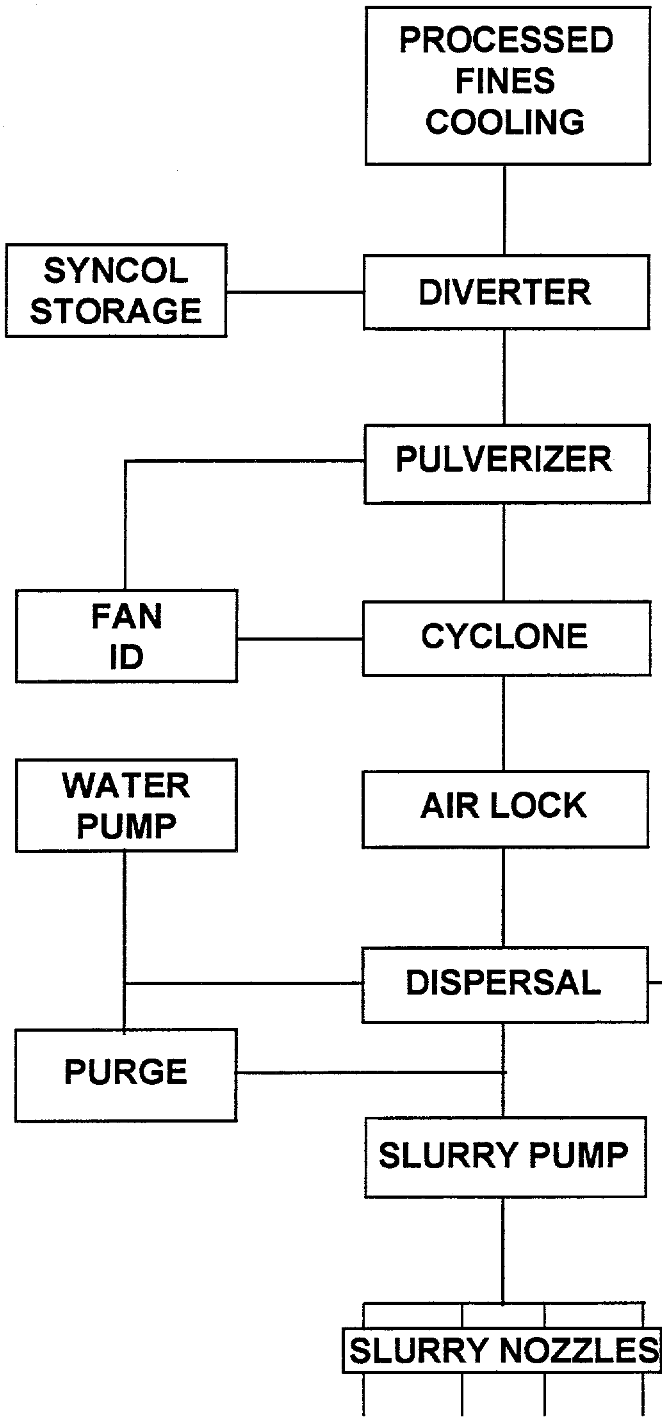


Figure 6.3 Proposed Syncol System Sub-Bituminous

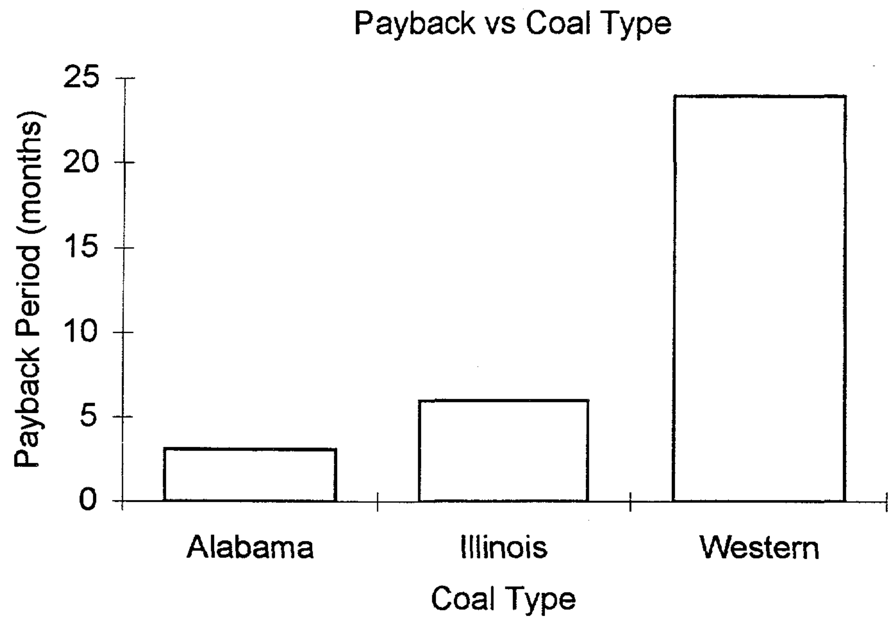


Figure 6.4 Comparison of Payback Periods of Systems Using Various Coals

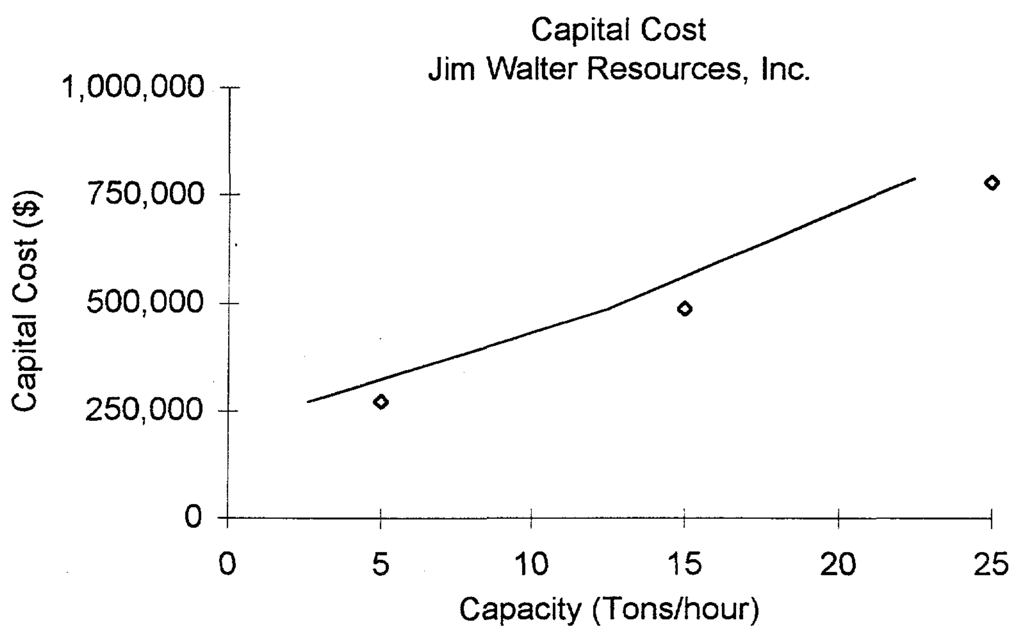


Figure 6.5 Capital Cost for the Jim Walter Resources Application at Various Capacities

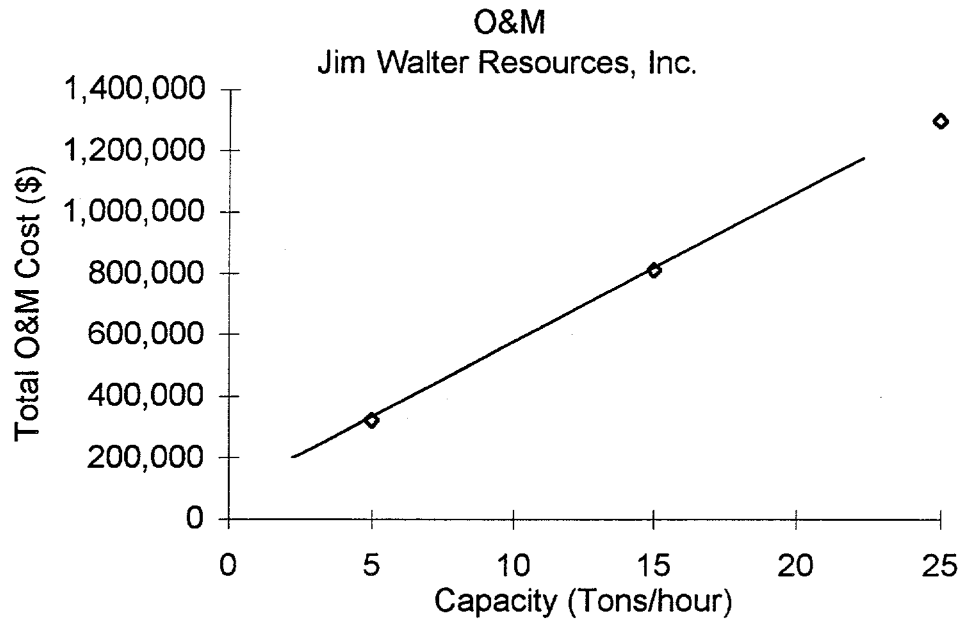


Figure 6.6 Operating and Maintenance Costs for the Jim Walter Resources Application at Various Capacities

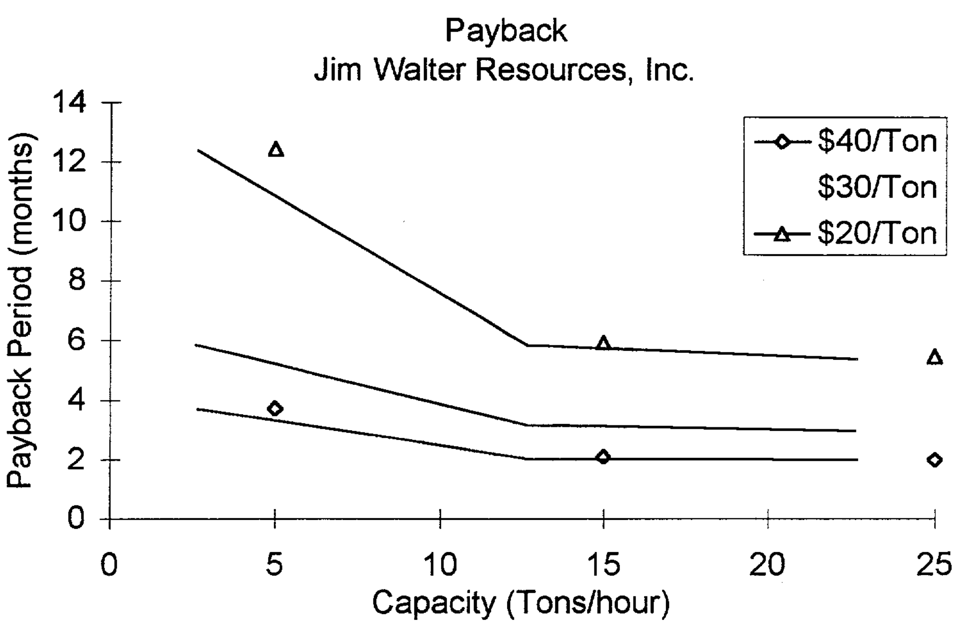


Figure 6.7 Payback Period for the Jim Walter Resources Application at Various Capacities

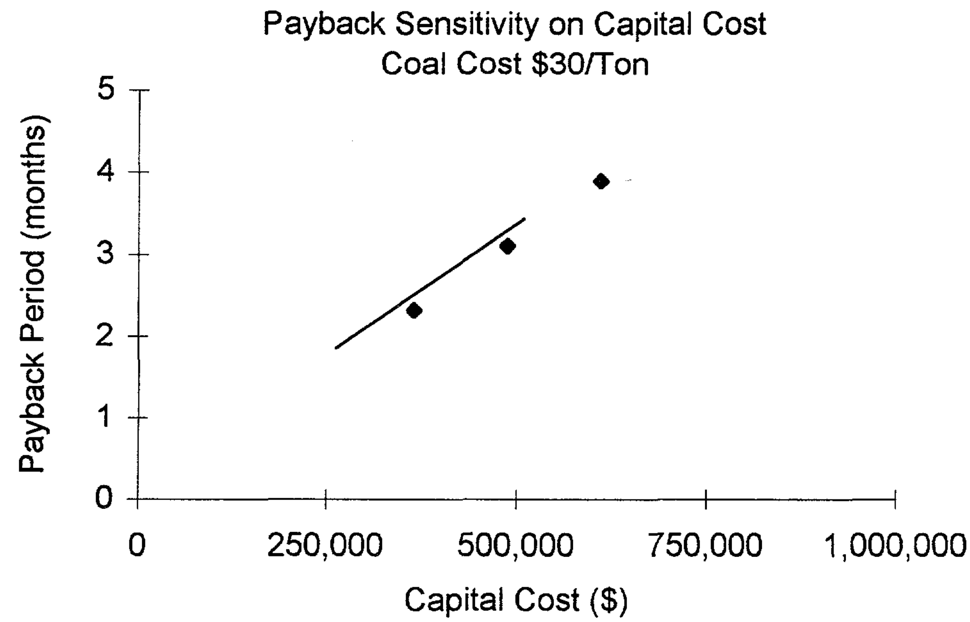


Figure 6.8 Sensitivity of the Payback Period on Capital Cost

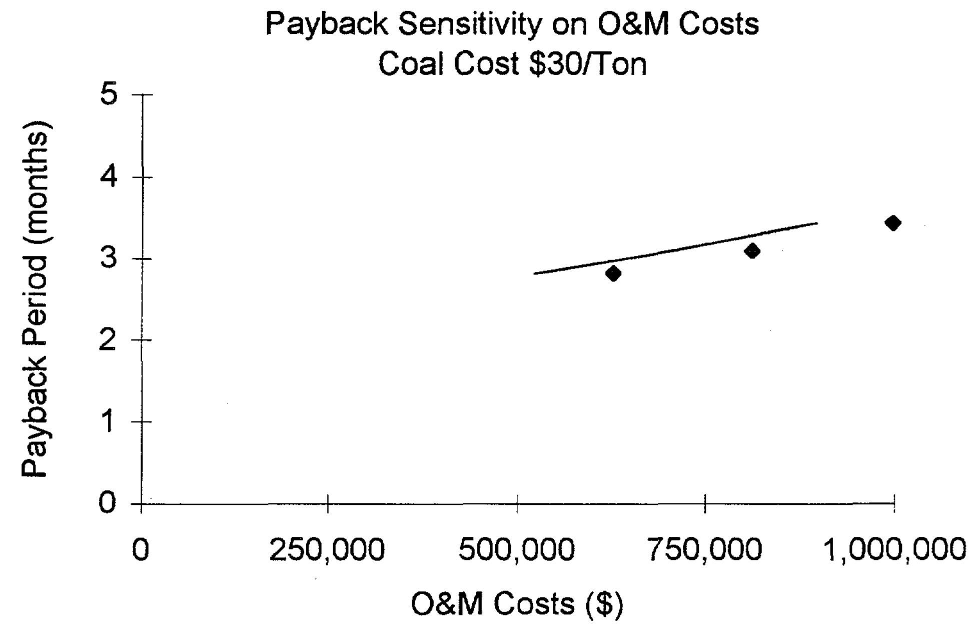


Figure 6.9 Sensitivity of the Payback Period on Operating and Maintenance Costs

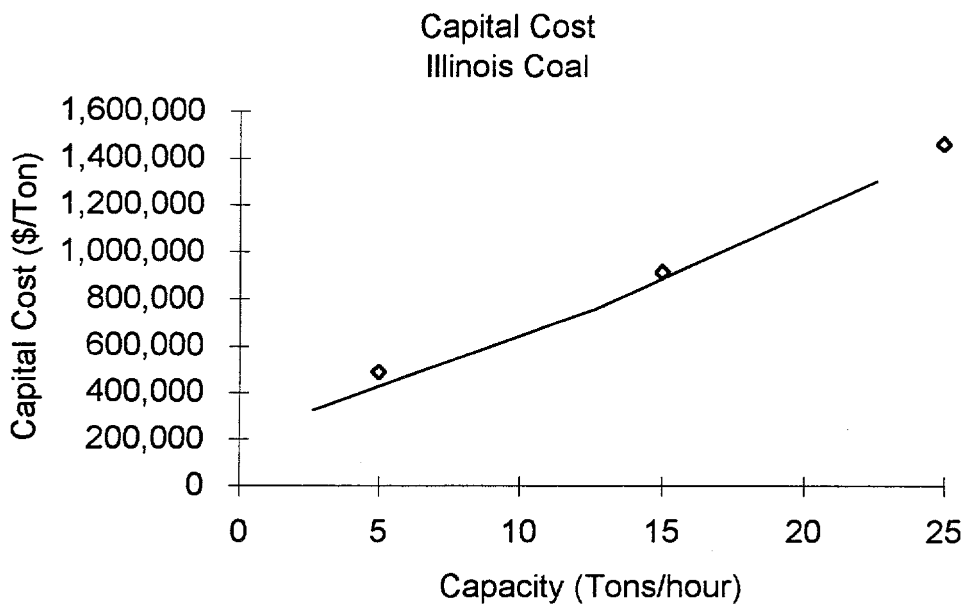


Figure 6.10 Capital Cost of the Illinois Coal Alternative

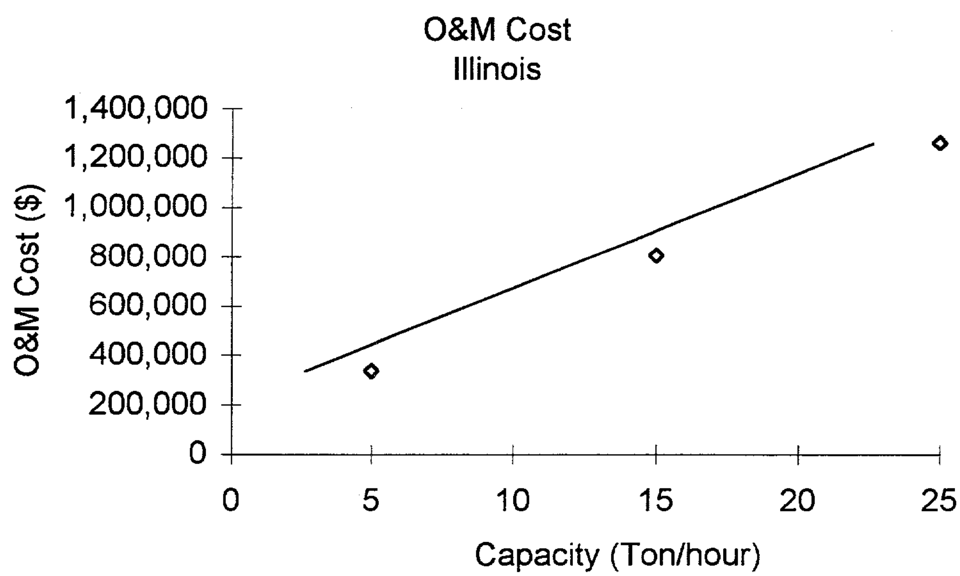


Figure 6.11 Operating and Maintenance Costs of the Illinois Coal Alternative

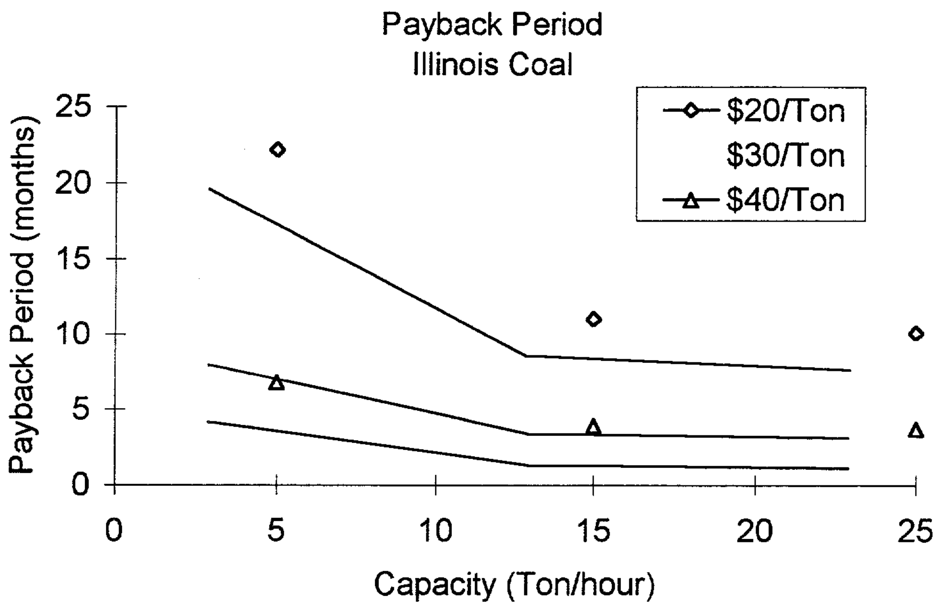


Figure 6.12 Payback Periods for the Illinois Coal Application for Various Coal Costs

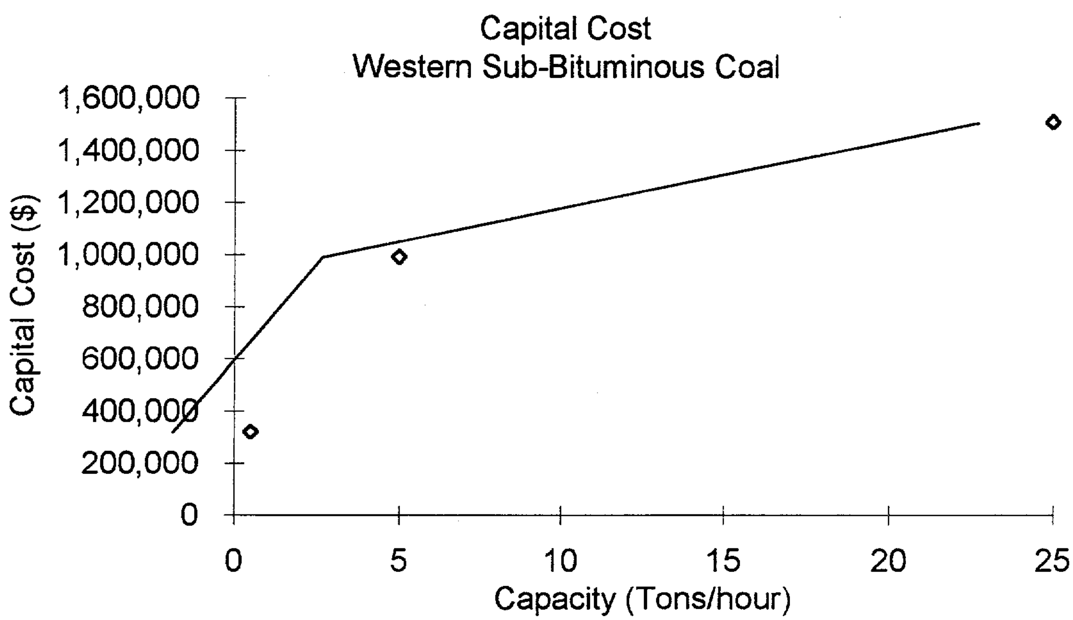


Figure 6.13 Capital Costs for the Western Coal Application

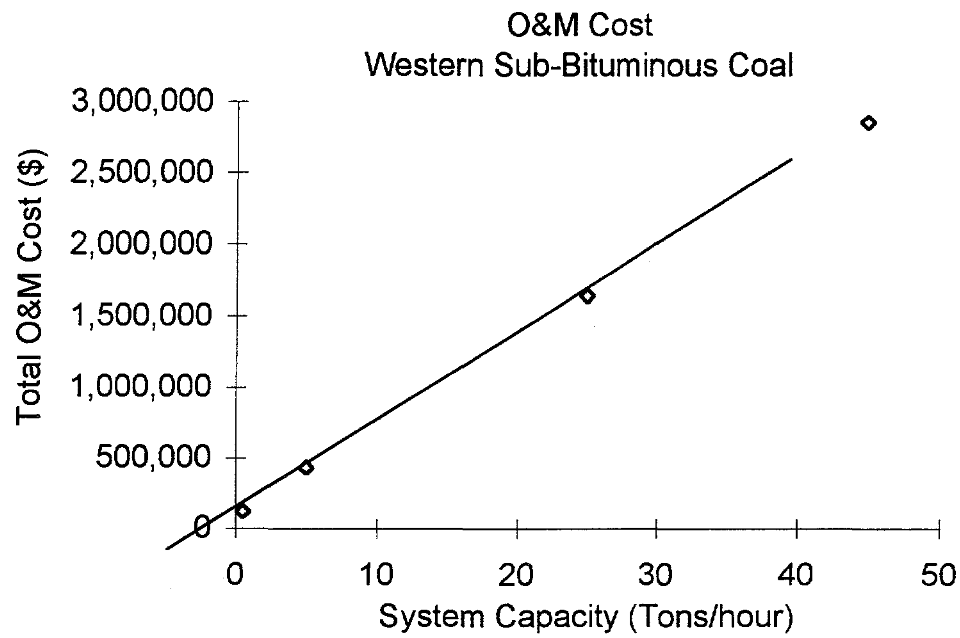


Figure 6.14 Operating and Maintenance Costs for the Western Coal Alternative

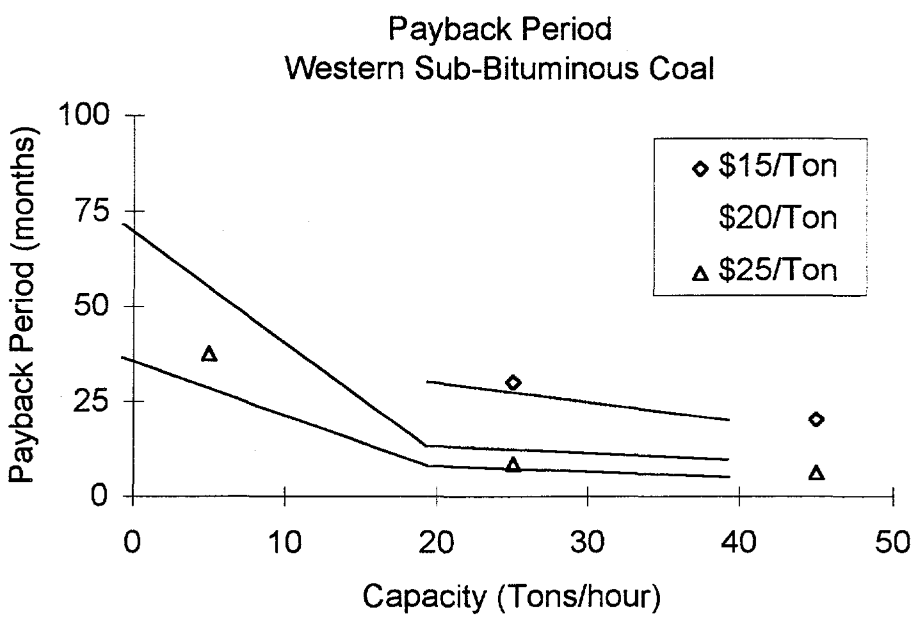


Figure 6.15 Payback Periods for the Western Coal Application for Various Coal Costs

APPENDICES

APPENDICES

A1 - STATEMENT OF WORK

The following statement of work (SOW) covers all nine tasks of the program, leading to the successful completion of a full-scale, POC test of a coal fines recovery and reuse ET at a well-run commercial coal processing plant. As the test site coal plant already has segregated their scrubber effluent in a clean ultrafine coal thickener, only the belt press needs to be added to form the complete flow loop. Consequently, a detailed description of the belt press' installation, as well as the five-month test program, are detailed below.

Task 1: Project and Test Planning

Tecogen will conduct project planning and prepare a test plan. The project planning will focus on planning the various aspects of designing, installing, commissioning and decommissioning the ET that will be tested. Included in the project planning will be the submission of Draft and Final National Environmental Policy Act (NEPA) reports. The test plan will detail the planned comprehensive test of the ET.

Task 2: ET Engineering and Design

Tecogen will be responsible for providing all engineering and design work for integration of the coal fines recovery and re-use POC demonstration at JWRI Mine Number 4. In this work, overall as well as individual subsystem performance specifications will be performed, process and controls diagrams will be made, and bid specifications will be prepared. Bids will be tendered and evaluated, in order to select the optimum bid. The preliminary engineering drawings will be revised to incorporate pertinent design details of the selected equipment.

Task 3: ET Procurement and Fabrication

All required system components will be purchased or fabricated and delivered to JWRI Mine Number 4. Six complete sets of all installation, operation, and maintenance manuals, included recommended spare parts lists, will be prepared.

Task 4: ET Installation and Shakedown

This task prepares the POC demonstration site, installs all component equipment at the site, checks out the installed equipment and the mechanical and electrical subsystems, and finally cleans the installation area. These tasks are conducted sequentially.

Task 5: Sample Analysis and Characterization

One portion of this task involves tests that are site-specific, and applies only to JWRI Mine Number 4, the POC demonstration site. A second portion involves support work to be performed by The University of Alabama, involving coals from both JWRI Mine Number 4 and other mines. Lastly, equipment manufacturer laboratory and/or subscale tests will be conducted to verify the recovery potential of CWM from other dryer's exhaust scrubber effluent.

Task 6: ET Operation/Testing

Tecogen will be responsible for operating the full-scale POC demonstration, recovering CWM from thermal dryer scrubber effluent for use as a dry coal de-dusting agent. The POC system will be operated for an elapsed time of five months, which is of sufficient duration to obtain test results that are credible to industry. Process technical and economic data will be recorded that documents the technology's operation.

Task 7: ET Technical and Economic Evaluation

A technical and economic evaluation will be conducted to determine the technical applicability of the CWM recovery/de-dusting system for representative coals nationwide. At least one Eastern and one Western coal will be selected, in addition to JWRI Mine Number 4. The result of this task will be to quantify the technical and economic applicability of the proposed process across the U.S.

Task 8: ET Decommissioning and Removal

It is planned to leave the equipment in place at the completion of the POC test. Consequently, only a limited amount of equipment will be decommissioned and removed to inventoried storage at the completion of the test. This equipment will include special test equipment that is not normally needed in a commercial facility. Additionally, residual test debris and waste will be removed, leaving JWRI Mine Number 4 in a clean and safe condition.

Task 9: Project Management

The purpose of this task is to ensure timely completion of all program objectives within the budgeted cost. The Tecogen Program Manager will set goals, plan how to accomplish these goals, maintain effective personnel on the project, negotiate and administer agreements between all participants, including subcontractors, and deliver all contract commitments and respond to DOE's Contracting Officer's Representative (COR). Periodic status and other report obligations will be submitted to document and summarize the POC demonstration.

A2 - MECHANICAL INSTALLATION DRAWINGS

EQUIPMENT SCHEDULE

TK-10	TK-60	AG-80	BP-50	FM-60	D-95
TK-20	TK-80	PB-15	AC-53	IM-62	FM-95
TK-30	AG-30	PB-25	BS-60	RD-80	FM-51
TK-40	AG-40	RS-70	D-60	DC-52	BS-95
TK-55	TK-95	TK-90			

PUMP SCHEDULE

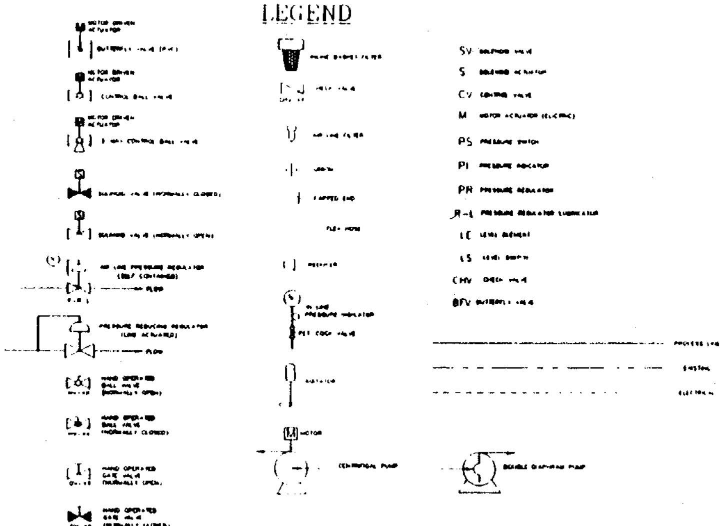
P-141	P-163
P-161	P-171
P-155	P-195
P-110	P-162
P-190	

REV	DESCRIPTION	DATE	BY	APPR
1	THROUGH OUT	10-12-84	RWL	
2	CHANGE PIPING MAT'L FROM PVC TO SCH 80 HDPE	10-31-84	RWL	

PIPING SCHEDULE

LINE NAME	PROCESS	MATERIAL
F	FeCL 1820A 1589C	SCH 40 PVC
MW	MILL WATER	COPPER TUBING
WR	WATER RETURN	EXISTING
SF	SCRUBBER FEED	EXISTING
SR	SCRUBBER RETURN	EXISTING
TO	THICKENER OVERFLOW	EXISTING
TUB	THICKENER UNDERFLOW BY-PASS	SCH 40 PVC
TUS	THICKENER UNDERFLOW SUPPLY	HIGH DENSITY POLYETHLENE (HDPE) 2" & ABOVE
BWE	BELT PRESS WATER EFFLUENT	HIGH DENSITY POLYETHLENE (HDPE) 2" & ABOVE
SP	SLURRY PROCESS	HIGH DENSITY POLYETHLENE (HDPE) 2" & ABOVE
SB	SLURRY BY-PASS	HIGH DENSITY POLYETHLENE (HDPE) 2" & ABOVE
FW	FILTRATE/WASH DISCHARGE	HIGH DENSITY POLYETHLENE (HDPE) 2" & ABOVE
MF	MIXED FLOC	HIGH DENSITY POLYETHLENE (HDPE) 2" & ABOVE
TUS	THICKENER UNDERFLOW SUPPLY	SCH 80 PVC UNDER 2"
BWE	BELT PRESS WATER EFFLUENT	SCH 80 PVC UNDER 2"
SP	SLURRY PROCESS	SCH 80 PVC UNDER 2"
SB	SLURRY BY-PASS	SCH 80 PVC UNDER 2"
FW	FILTRATE/WASH DISCHARGE	SCH 80 PVC UNDER 2"
MF	MIXED FLOC	SCH 80 PVC UNDER 2"
BF	BY PASS	COPPER TUBING
S	SURFACANT	SCH 40 PVC
CA	COMPRESSED AIR	COPPER TUBING
PR	POLYMER RECIRCULATION	SCH 40 PVC

LEGEND



NOTE

FOR DETAIL PIPING AND VALVE SCHEDULE SEE SCHEDULE SHEETS

1. PIPING - SCH-456P SHEETS 1 THRU 3
2. MANUAL VALVES - SCH-456V SHEETS 1 THRU 3

APPROVED FOR CONSTRUCTION

DATE ______ BY ______

TECOGEN
45 FIRST AVENUE WALTHAM, MA 02254-8046

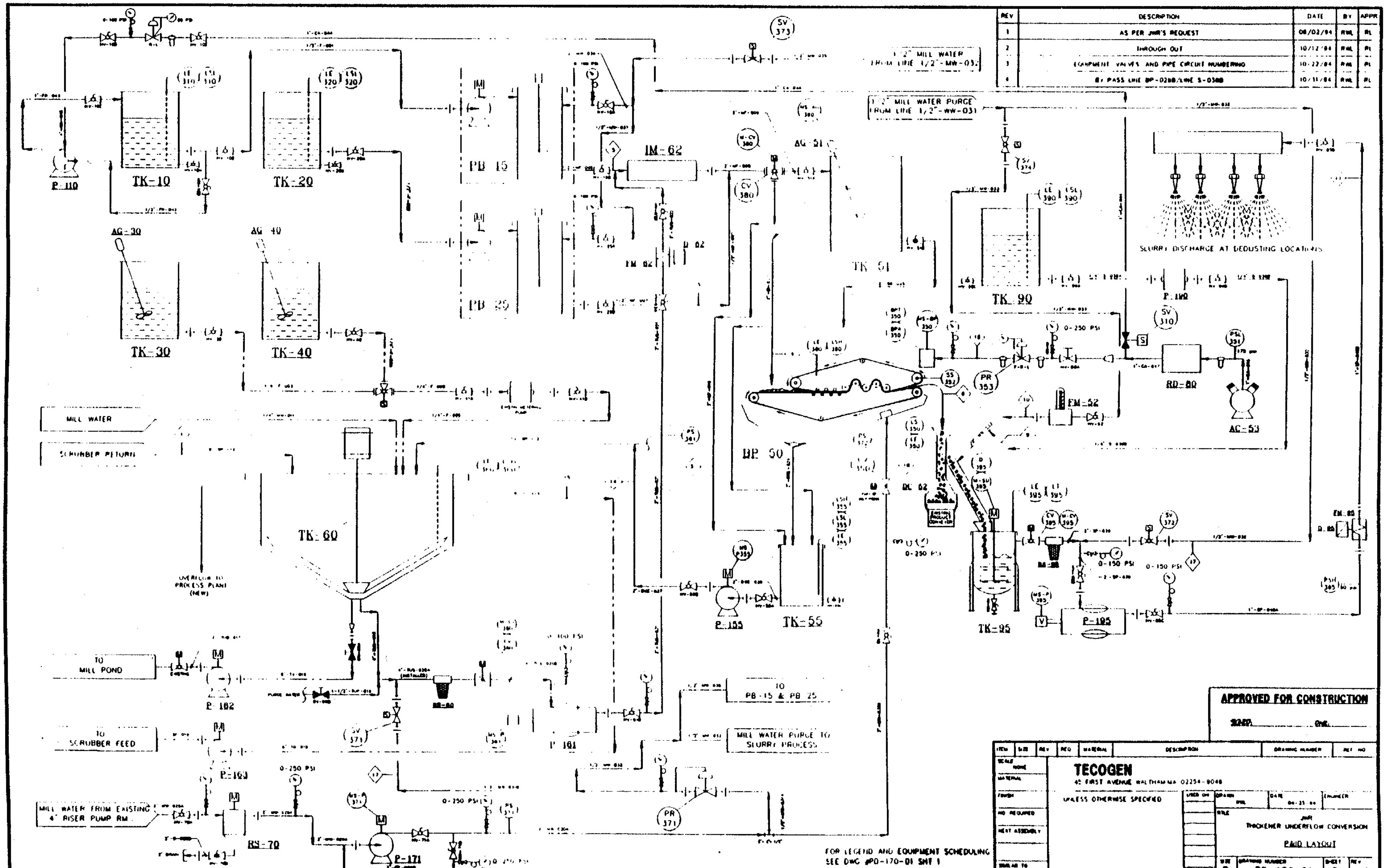
UNLESS OTHERWISE SPECIFIED

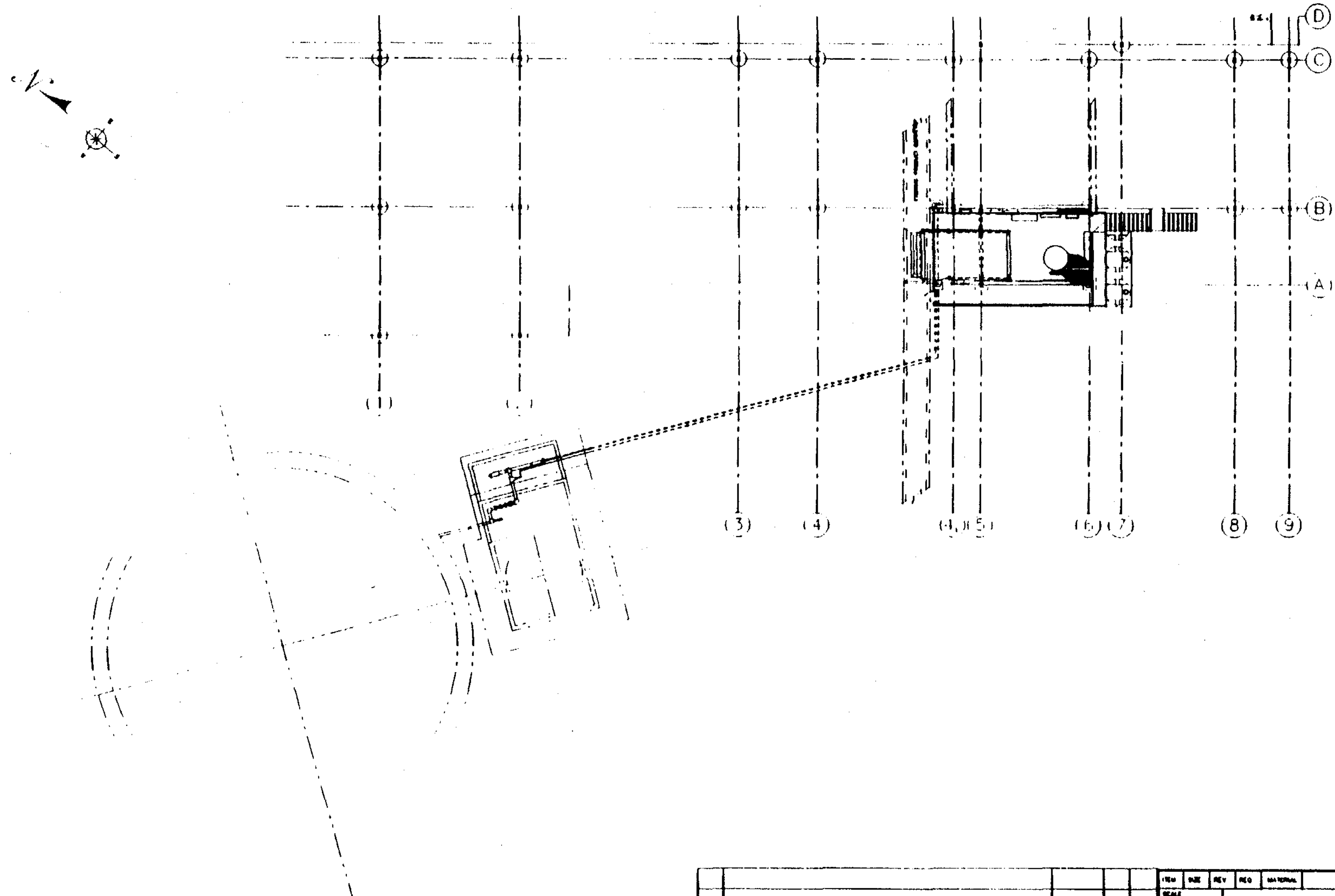
DRAWN RWL — DATE 04-30-84

TITLE: THICKENER UNDERFLOW CONVERSION — LEGEND AND MAT'L SCHEDULING

SIZE D — DRAWING NUMBER PD-170-01 — SHEET 1 — REV 2

170-01-2


REV | DESCRIPTION | DATE | BY | APPR
1 | AS PER JWR'S REQUEST | 08/02/84 | RWL | RL
2 | THROUGH OUT | 10/12/84 | RWL | RL
3 | EQUIPMENT, VALVES AND PIPE CIRCUIT NUMBERING | 10/22/84 | RWL | RL
4 | BY PASS LINE BP-028B/LINE S-038B | 10/31/84 | RWL | RL
P-110
TK-10
TK-20
TK-30
TK-40
AG-30
AG-40
PB 15
PB 25
IM-62
FM 62
AG-51
TK-51
TK-60
TK-90
TK-55
TK-95
BP 50
P-155
P-190
RD-80
AC-53
FM-52
DC 62
P-195
P-182
P-181
P-171
RS-70
MILL WATER
SCRUBBER RETURN
OVERFLOW TO PROCESS PLANT (NEW)
TO MILL POND
TO SCRUBBER FEED
MILL WATER FROM EXISTING 4" RISER PUMP RM.
TO PB-15 & PB-25
MILL WATER PURGE TO SLURRY PROCESS
1/2" MILL WATER FROM LINE 1/2"-MW-032
1/2" MILL WATER PURGE FROM LINE 1/2"-WW-031
SLURRY DISCHARGE AT DEDUSTING LOCATIONS
0-250 PSI
0-150 PSI
FOR LEGEND AND EQUIPMENT SCHEDULING SEE DWG #PD-170-01 SHT 1
APPROVED FOR CONSTRUCTION
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046
UNLESS OTHERWISE SPECIFIED
THICKENER UNDERFLOW CONVERSION
P&ID LAYOUT
PD-170-01
SIZE D
SHEET 2
REV 4



REFERENCE DRAWINGS

BELT PRESS LAYOUT PLAN
GRADE LEVEL LAYOUT PLAN
EQUIPMENT LAYOUT ELEVATION
THICKENER PUMP ROOM LAYOUT PLAN

STRUCTURAL STEEL LAYOUT PLAN
STRUCTURAL STEEL ELEVATION
STRUCTURAL STEEL FOOTING DETAILS
CONCRETE SLABS PLAN
CONCRETE SLAB DETAILS
NEW STRUCTURAL STAIRS PLAN
NEW STRUCTURAL STAIRS ELEVATION

SITE LAYOUT PLAN
GRADE LEVEL PIPING PLAN
THICKENER PUMP ROOM PIPING

AC INTERNAL WIRING DIAGRAM
DC INTERNAL WIRING DIAGRAM
AC EXTERNAL WIRING DIAGRAM
FACILITY HIGH VOLTAGE WIRING DIAGRAM 1
DC EXTERNAL WIRING DIAGRAM
BELT PRESS PANEL AND CONDUIT RUN PLAN
GRADE LEVEL PANEL AND CONDUIT RUN
FACILITY HIGH VOLTAGE WIRING DIAGRAM-2
GRADE LEVEL INSTRUMENT CONDUIT RUN
GRADE LEVEL EQUIPMENT CONDUIT RUN
THICKENER PUMP RM EQUIP & INSTRUMENT CONDUIT RUN
THICKENER ELECTRICAL SITE PLAN

SLAB SECTION
INSERT AND SLIP FLANGE
SECTION SLEEVE

REV	DESCRIPTION	DATE	BY	APPR
1				

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE 1/8" = 1'-0"

TECOGEN

UNLESS OTHERWISE SPECIFIED

DRAWN: RWL | DATE: 06-20-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC)
THICKENER TANK UNDERFLOW SITE
PLAN VIEW

SIZE	DRAWING NUMBER	SHEET	REV
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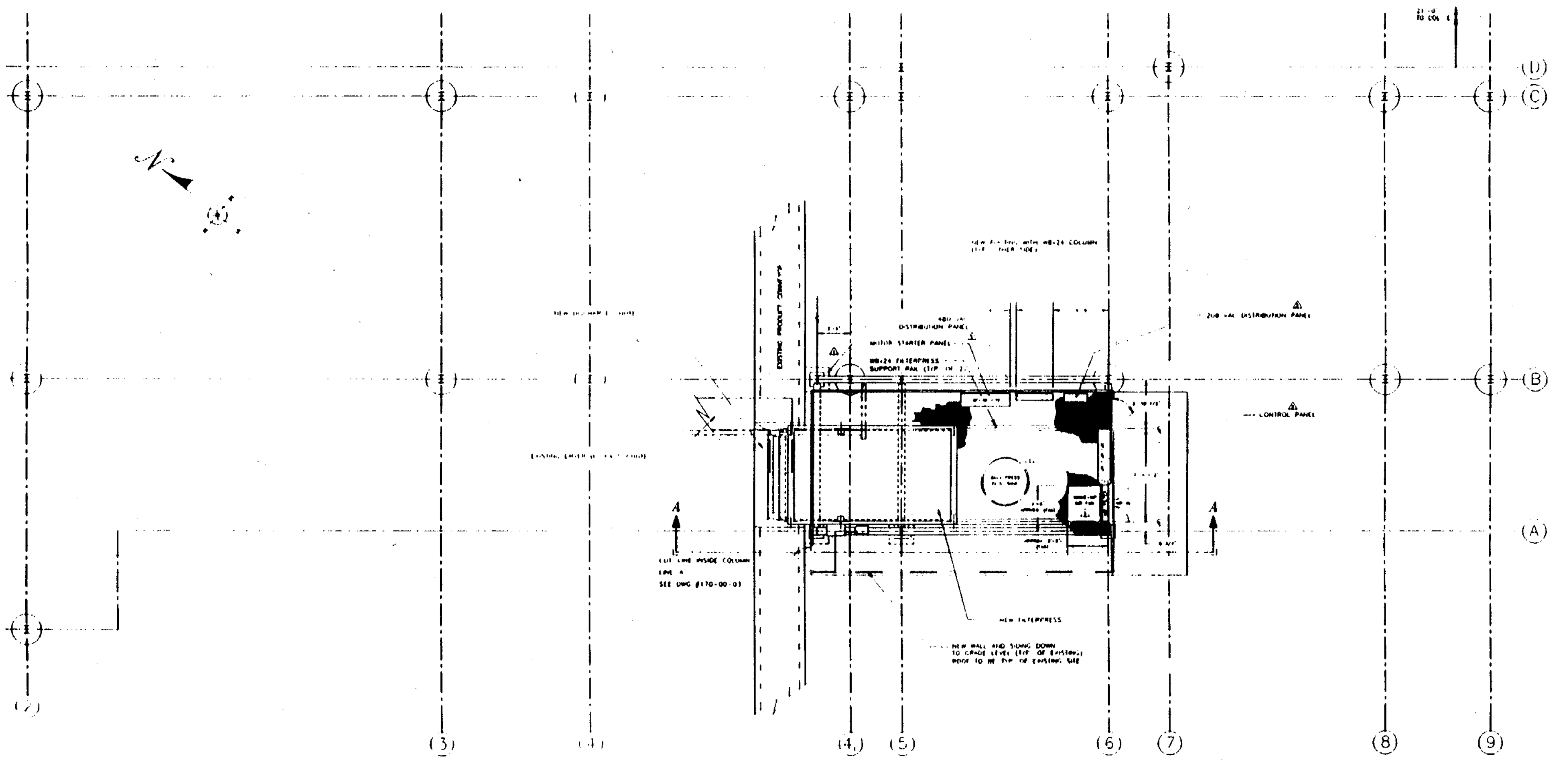
CONSTRUCTION AS-BUILT



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2	△	12/01/94	RML	
1	△	5-25-94	RML	

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

SCALE 1/4" = 1'-0"
ISSUE DATE 5/20/94
DRAWN RML
DATE 06-21-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC)
PLAN VIEW

SIZE	DRAWING NUMBER	SHEET	REV
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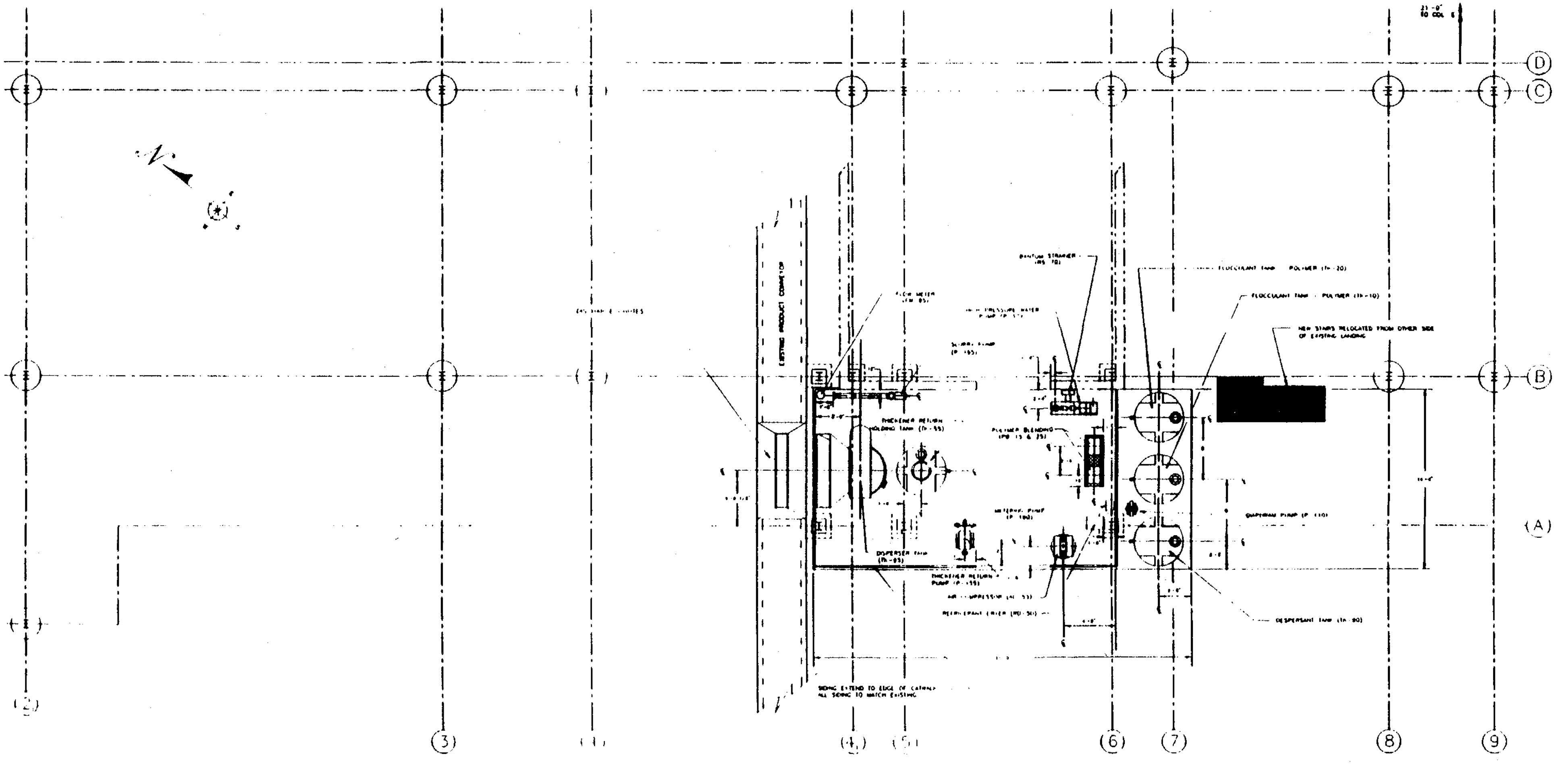
170-04-3



REV	DESCRIPTION	DATE	BY	APPR
2	ADDED METERING PUM (P-190)	12-27-94	RWL	
1	MOVED WALL AND EQUIPMENT AT "A" LINE TO EDGE OF CATWALK	11-03-94	RWL	

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE 1/4" = 1'-0"

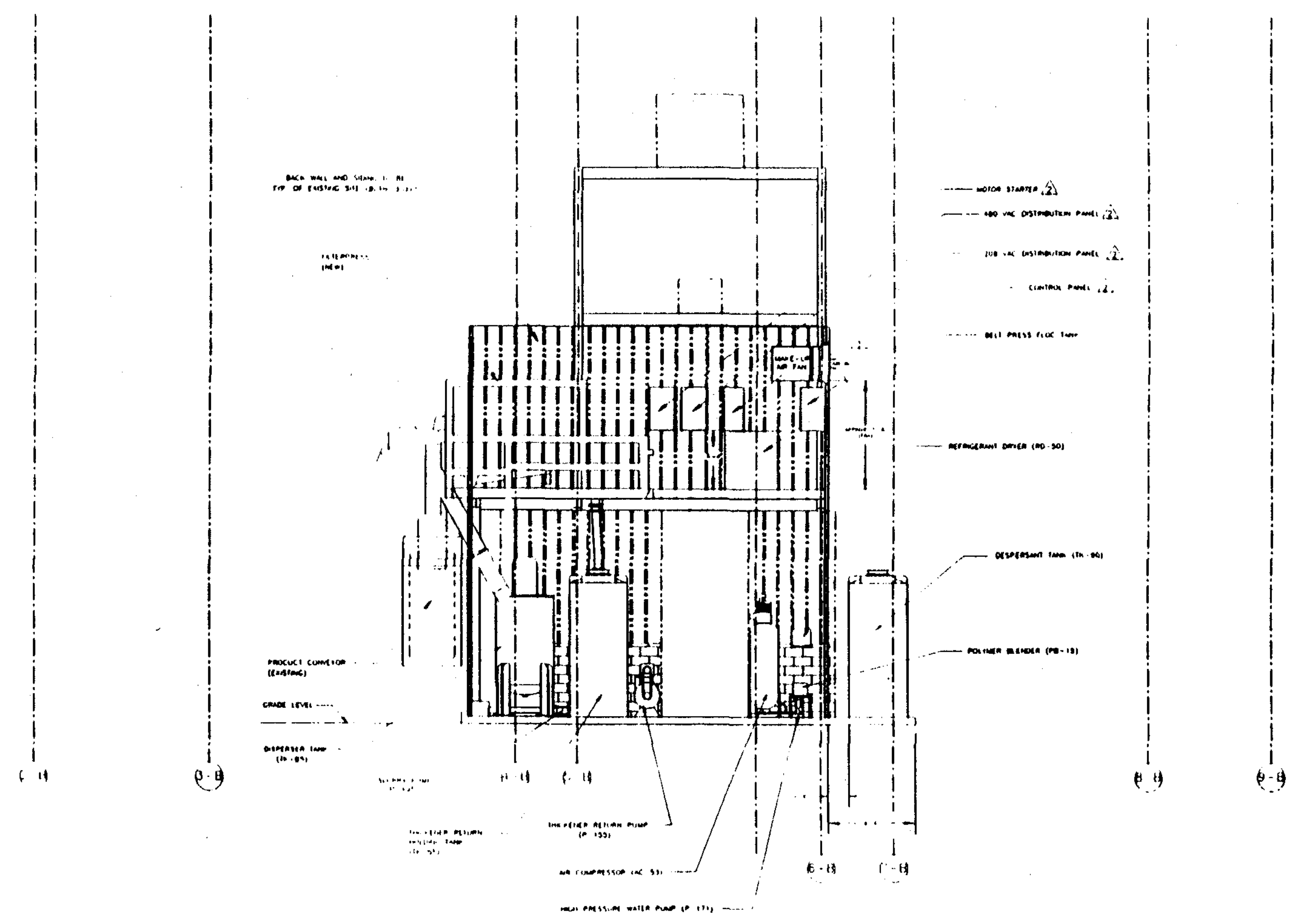
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

DRAWN RWL — DATE 06-02-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) EQUIPMENT LAYOUT (GRADE LEVEL) PLAN VIEW

SIZE D — DRAWING NUMBER M-170-02 — SHEET 3 — REV 1



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2	△2	12-01-94	RML	
1	△1	9-29-94	PML	

SCALE 1/4" = 1'-0"

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

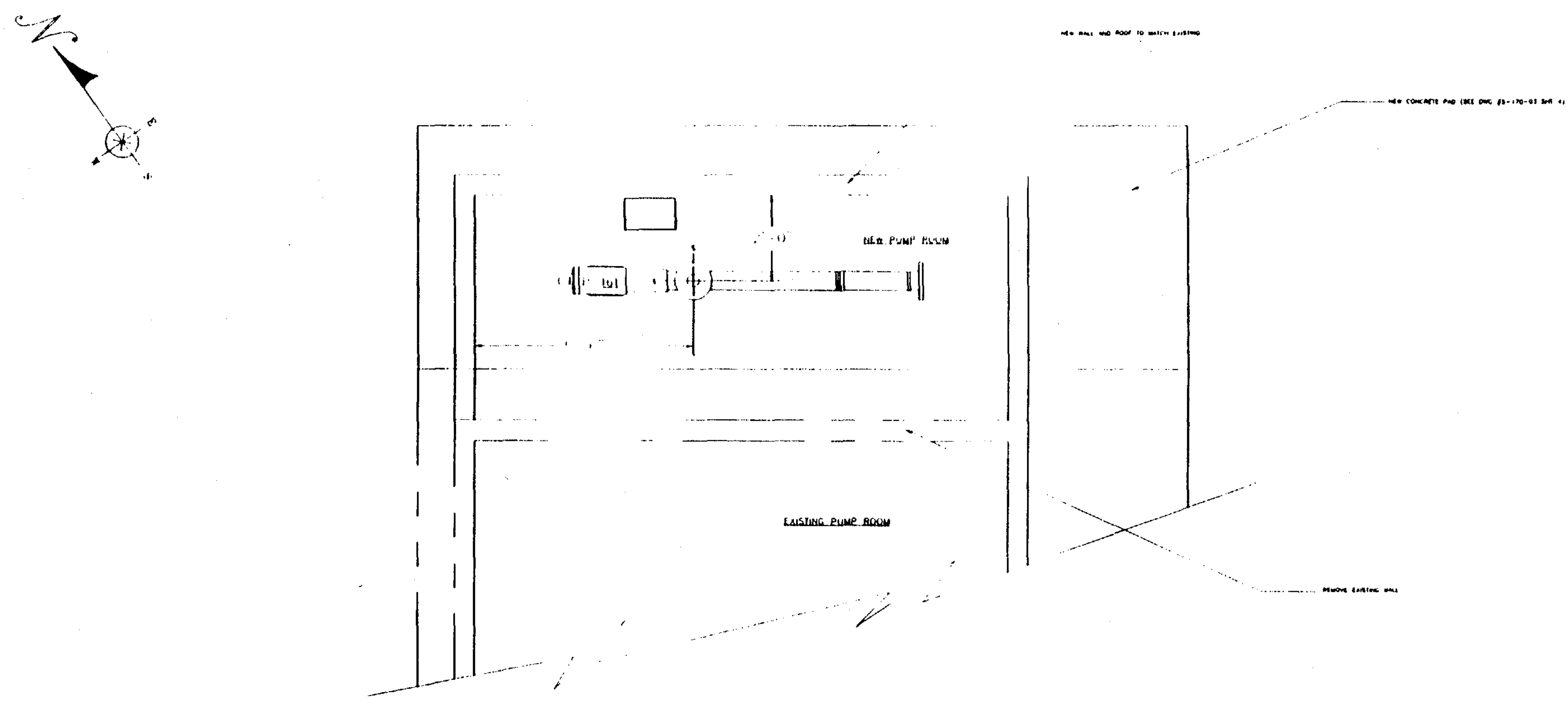
UNLESS OTHERWISE SPECIFIED

DRAWN RML DATE 05-02-94

ISSUE DATE 5/20/94

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
ELEVATION A-A

SIZE D | DRAWING NUMBER M-170-02 | SHEET 4 | REV 3



REF P&ID DWG PD-170-01 SHT 2

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION

SCALE 3/4" = 1'-0"

TECOGEN
45 FIRST AVENUE WALTHAM, MA 02254-9046

UNLESS OTHERWISE SPECIFIED

DRAWN RWL DATE 12-21-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) THICKENER PUMP RM EQUIP LAYOUT PLAN VIEW

SIZE D DRAWING NUMBER M-170-02 SHEET 5 REV 0

REV	DESCRIPTION	DATE	BY	APPR
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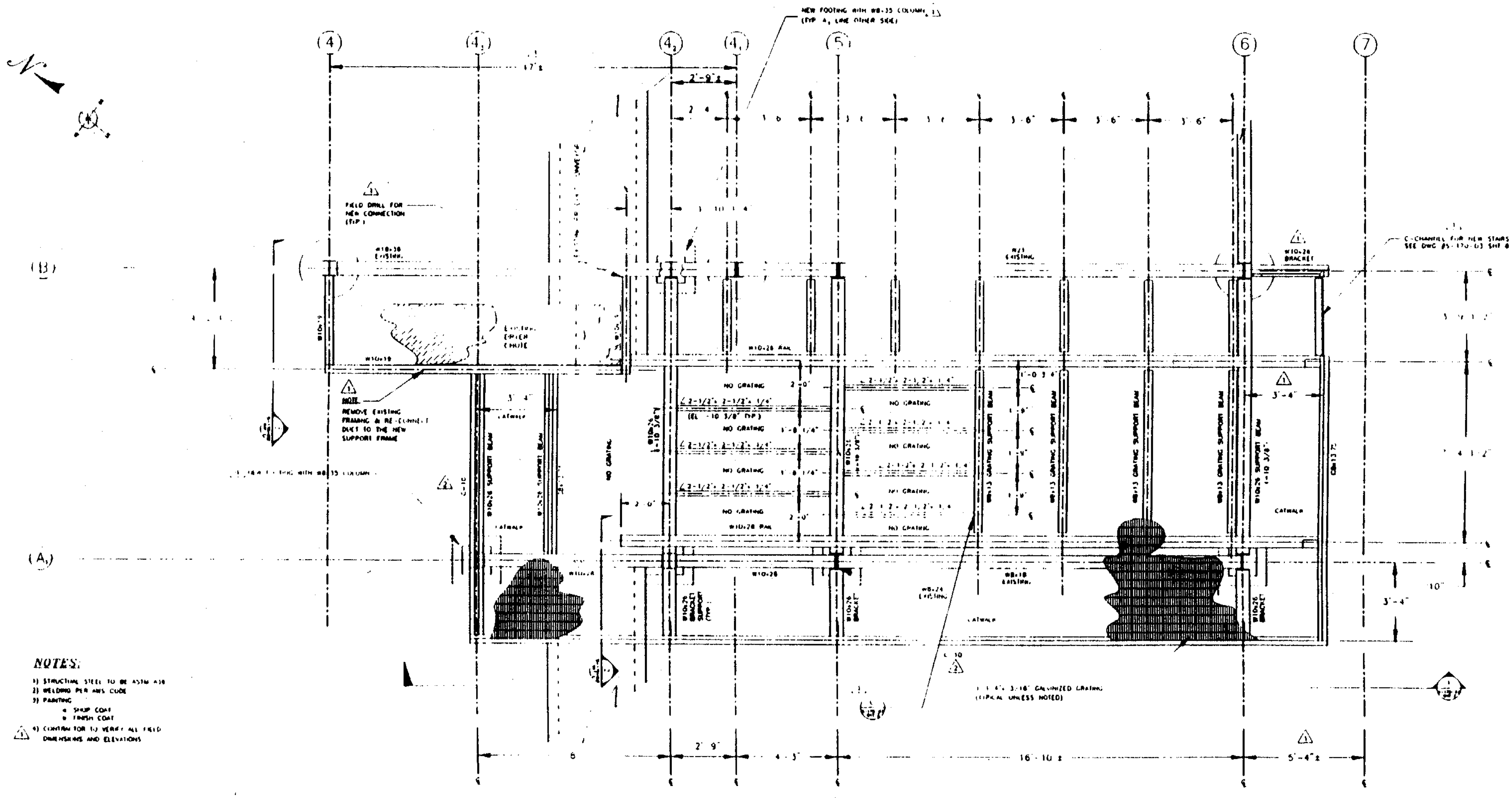

NOTES:

1) STRUCTURAL STEEL TO BE ASTM A36
2) WELDING PER AWS CODE
3) PAINTING
   a. SHOP COAT
   b. FINISH COAT
4) CONTRACTOR TO VERIFY ALL FIELD DIMENSIONS AND ELEVATIONS

FRAMING PLAN
(ELEVATIONS T.O.S. 435'-1-1/4" ± TYPICAL UNLESS NOTED)

REV	DESCRIPTION	DATE	BY	APPR
2	△2	10/31/94	RWL	
1	△1	09/14/94	RWL	

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

SCALE 1/2" = 1'-0"
ISSUE DATE 5/20/94
DRAWN RWL DATE 08-15-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) PLAN VIEW STRUCTURAL STEEL

SIZE	DRAWING NUMBER	SHEET	REV
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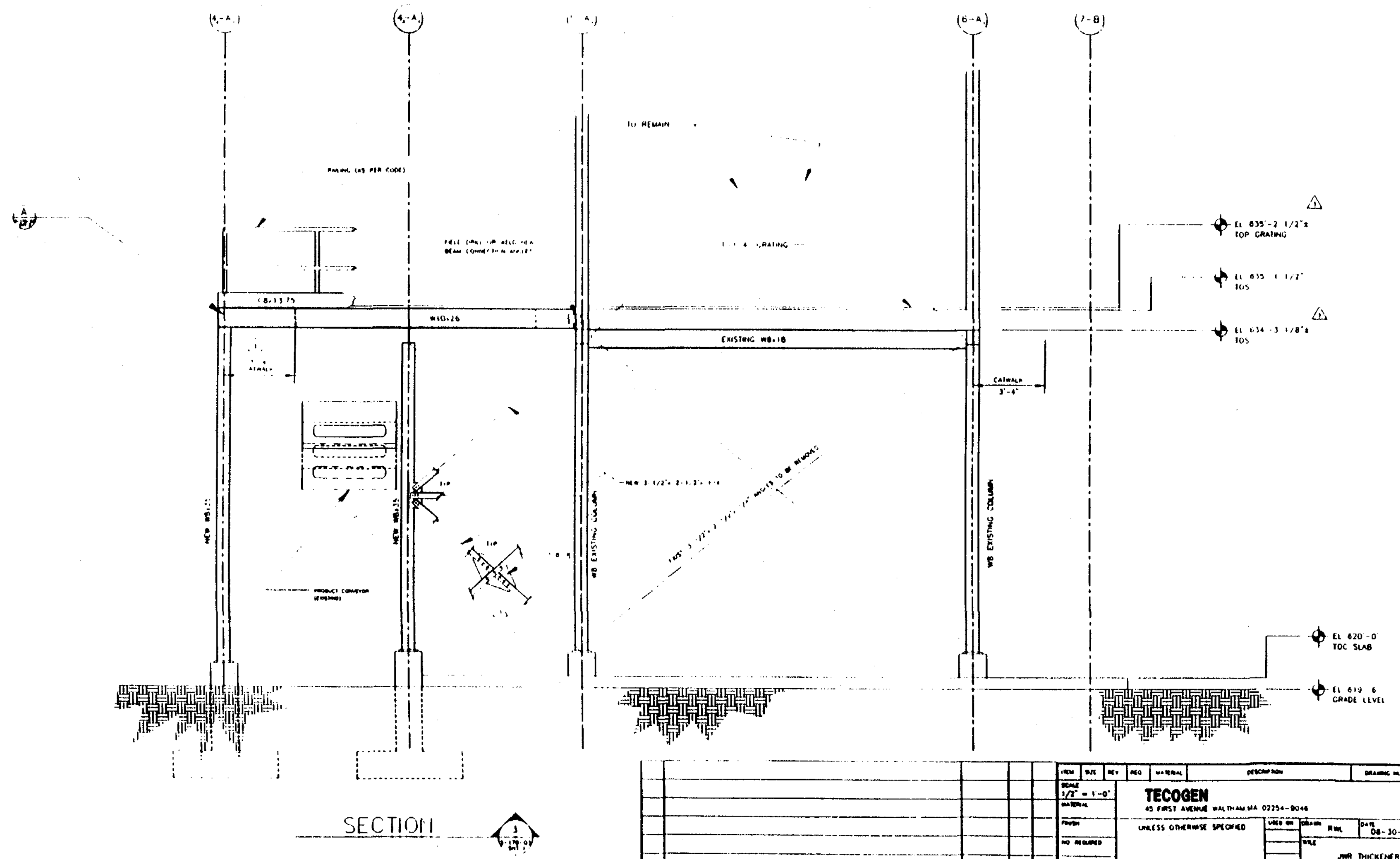


SECTION

REV	DESCRIPTION	DATE	BY	APPR
1	⚠1	09/18/84	RWL	

TECOGEN
45 FIRST AVENUE WALTHAM, MA 02254-9046

SCALE 1/2" = 1'-0"

UNLESS OTHERWISE SPECIFIED

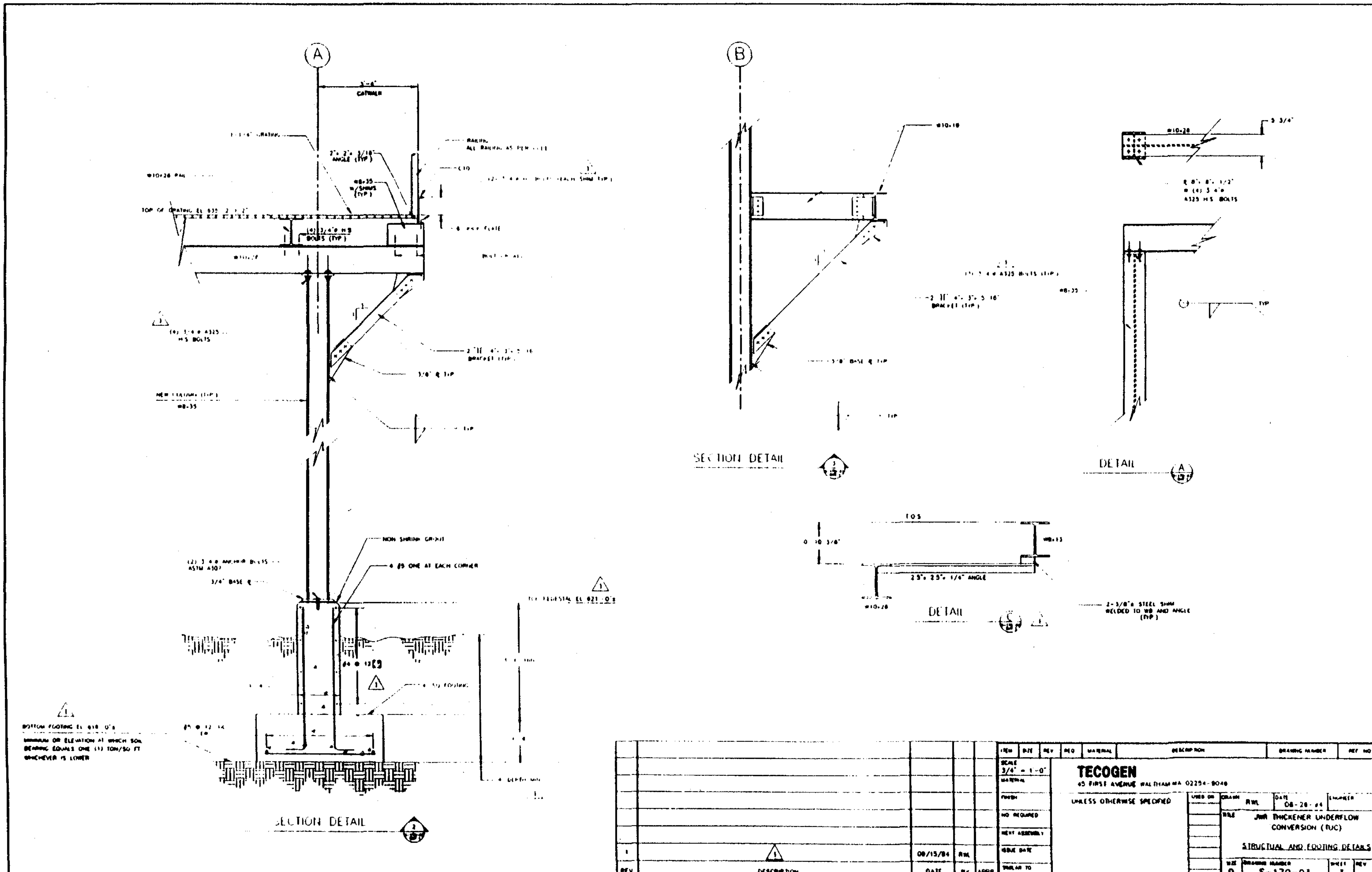
DRAWN RWL DATE 08-30-84

ISSUE DATE 5/20/84

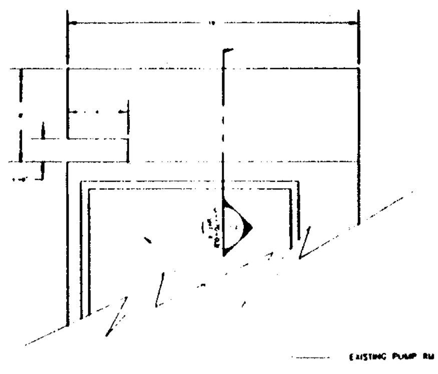
JWR THICKENER UNDERFLOW CONVERSION (TUC)

STRUCTURAL ELEVATION (3)

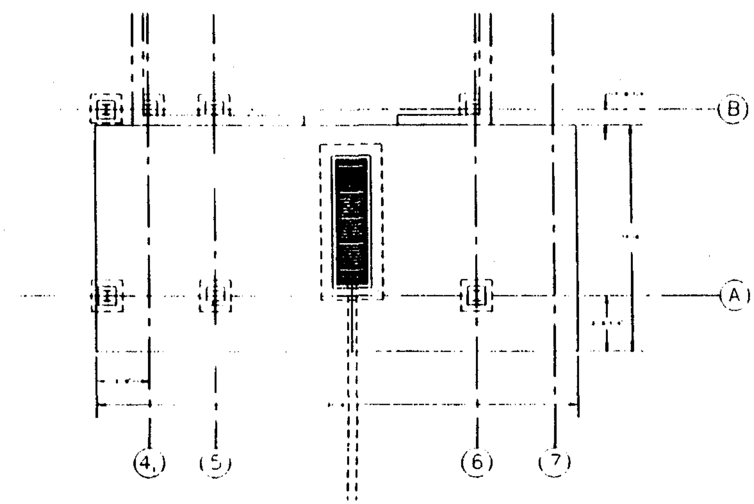
SIZE D DRAWING NUMBER S-170-03 SHEET 2 REV 1



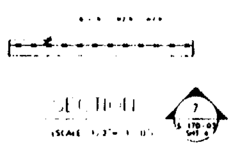
SECTION DETAIL
SECTION DETAIL
DETAIL
DETAIL
TOP OF GRATING EL 635'-2 1/2"
3'-4" CATWALK
NON SHRINK GROUT
4 #5 ONE AT EACH CORNER
3/4" BASE ℞
2.5"x 2.5"x 1/4" ANGLE
TOS
W10x28
W8x35
2-3/8"⌀ STEEL SHIM WELDED TO W8 AND ANGLE (TYP)
BOTTOM FOOTING EL 618'-0"± MINIMUM OR ELEVATION AT WHICH SOIL BEARING EQUALS ONE (1) TON/SQ FT WHICHEVER IS LOWER
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046
UNLESS OTHERWISE SPECIFIED
SCALE 3/4" = 1'-0"
JWR THICKENER UNDERFLOW CONVERSION (TUC)
STRUCTUAL AND FOOTING DETAILS
DATE 08-28-84
DRAWN RWL
08/15/84 RWL
D S-170-03 3 1



NEW THICKENER TANK PUMP RM
CONCRETE SLAB EXTENSION



NEW EQUIPMENT ROOM CONCRETE SLAB
(SEE DWG #S-170-03 SHT 4 FOR DETAILS)



SECTION
(SCALE 1/2" = 1'-0")

TECOGEN
45 FIRST AVENUE WALTHAM,MA 02254-9046

UNLESS OTHERWISE SPECIFIED

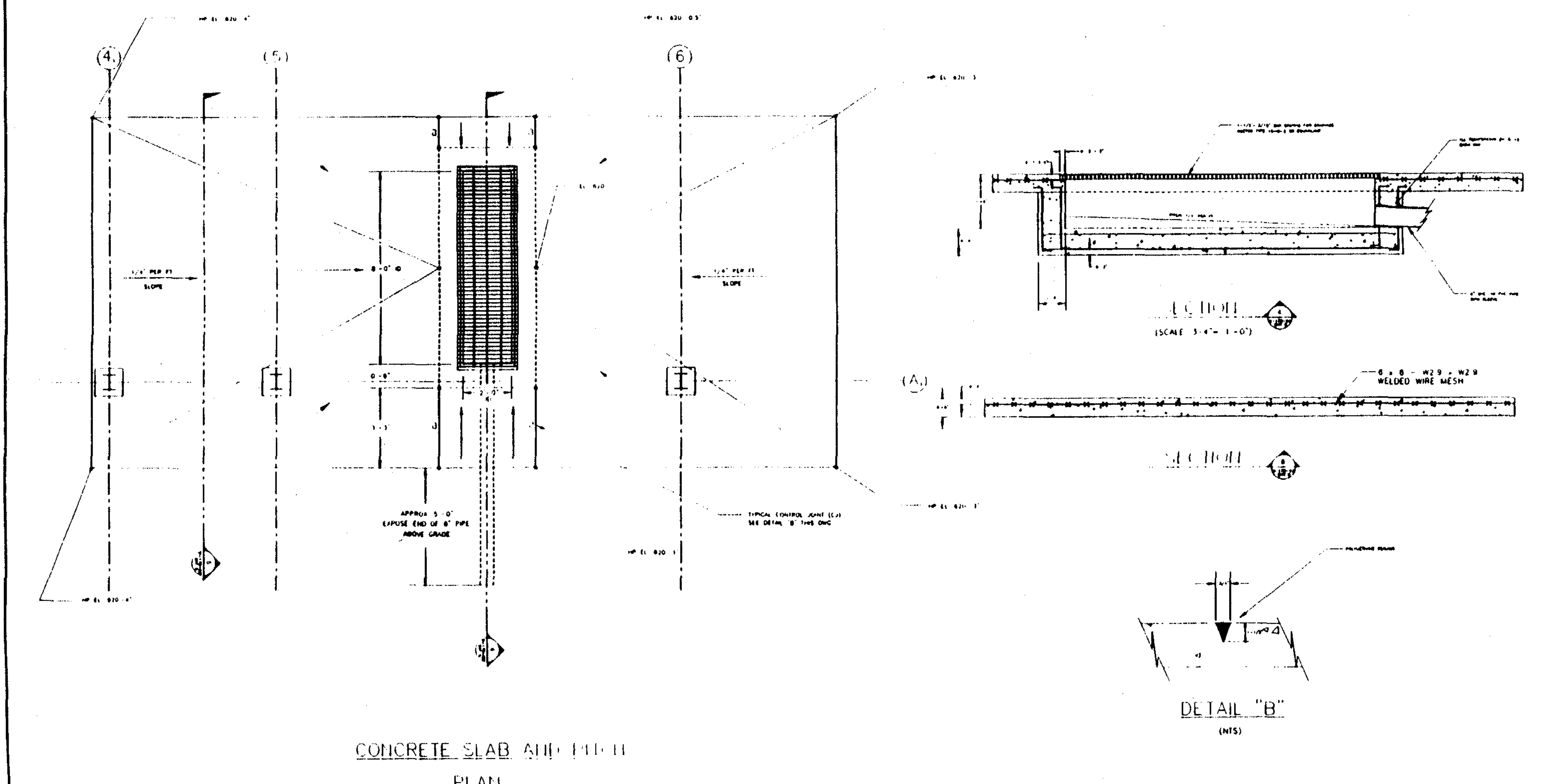
SCALE 1/4" = 1'-0"

DRAWN RWL | DATE 08-31-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) CONCRETE SLABS PLAN VIEW

SIZE	DRAWING NUMBER	SHEET	REV
D	S-170-03	4	0

REV	DESCRIPTION	DATE	BY	APPR
1				



REV	DESCRIPTION	DATE	BY	APPR
1	REBAR AND ADD COLUMN LINES	08/14/84	RWL	

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

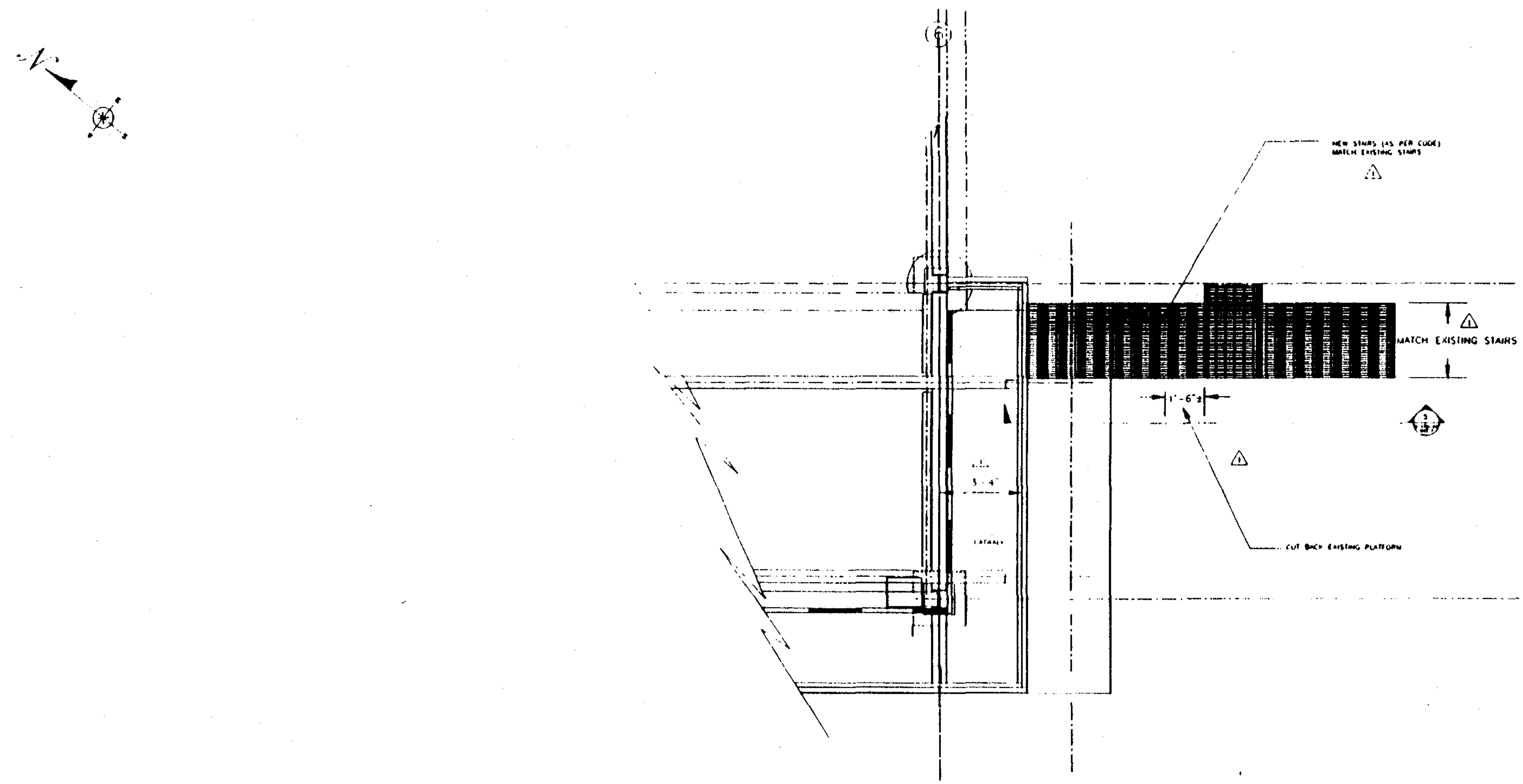
UNLESS OTHERWISE SPECIFIED

SCALE	1/2" = 1'-0"
MATERIAL	
FINISH	
NO REQUIRED	
NEXT ASSEMBLY	
ISSUE DATE	3/20/84
SIMILAR TO	

DRAWN: RWL — DATE: 08-30-84 — ENGINEER:

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
CONCRETE SLAB DETAILS

SIZE	DRAWING NUMBER	SHEET	REV
D	S-170-03	5	1



REV	DESCRIPTION	DATE	BY	APPR
1	⚠	09/16/94	RWL	

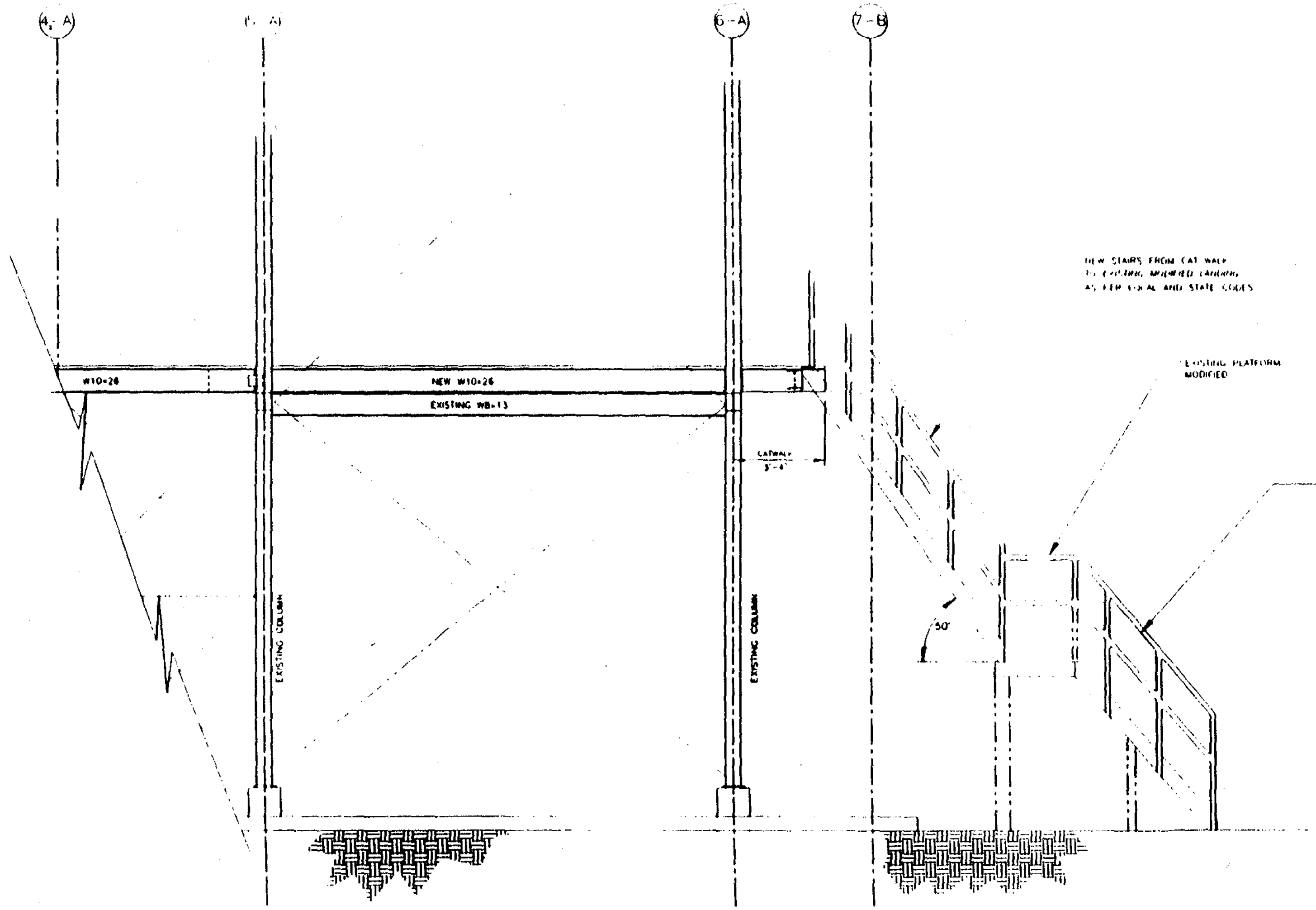
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

SCALE 1/2" = 1'-0"
ISSUE DATE 9/20/94
UNLESS OTHERWISE SPECIFIED

DRAWN RWL — DATE 09-01-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC)
NEW STAIRS
PLAN

SIZE D — DRAWING NUMBER S-170-05 — SHEET 6 — REV 0



SECTION 5 / S-170-03 / SHT 6

REV	DESCRIPTION	DATE	BY	APPR
1	REMOVED STAIR SUPPORT COLUMN	08/18/94	RWL	

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

TECOGEN
45 FIRST AVENUE WALTHAM, MA 02254-9046

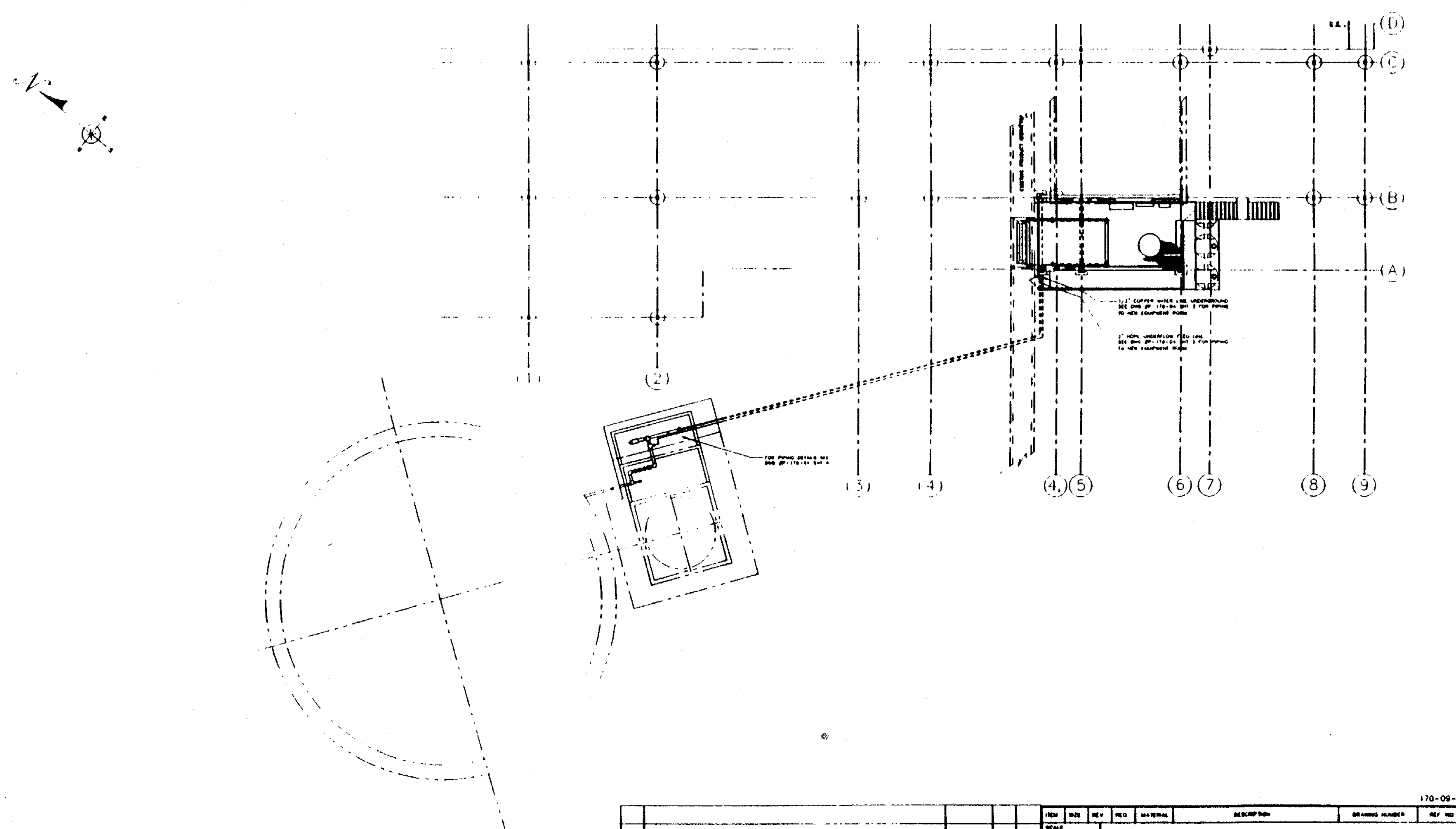
SCALE: 1/2" = 1'-0"
MATERIAL:
FINISH:
NO REQUIRED:
NEXT ASSEMBLY:
ISSUE DATE: 9/20/94
SIMILAR TO:

UNLESS OTHERWISE SPECIFIED

USED ON:
DRAWN: RWL
DATE: 09-01-94
ENGINEER:

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
NEW STAIRS
STRUCTUAL ELEVATION

SIZE: D
DRAWING NUMBER: S-170-03
SHEET: 7
REV: 1



170-09-0

REV	DESCRIPTION	DATE	BY	APPR
1				

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE 1/8" = 1'-0"
MATERIAL
FINISH
NO REQUIRED
NEXT ASSEMBLY
ISSUE DATE
SIMILAR TO

TECOGEN
45 FIRST AVENUE WALTHAM,MA 02254-9046

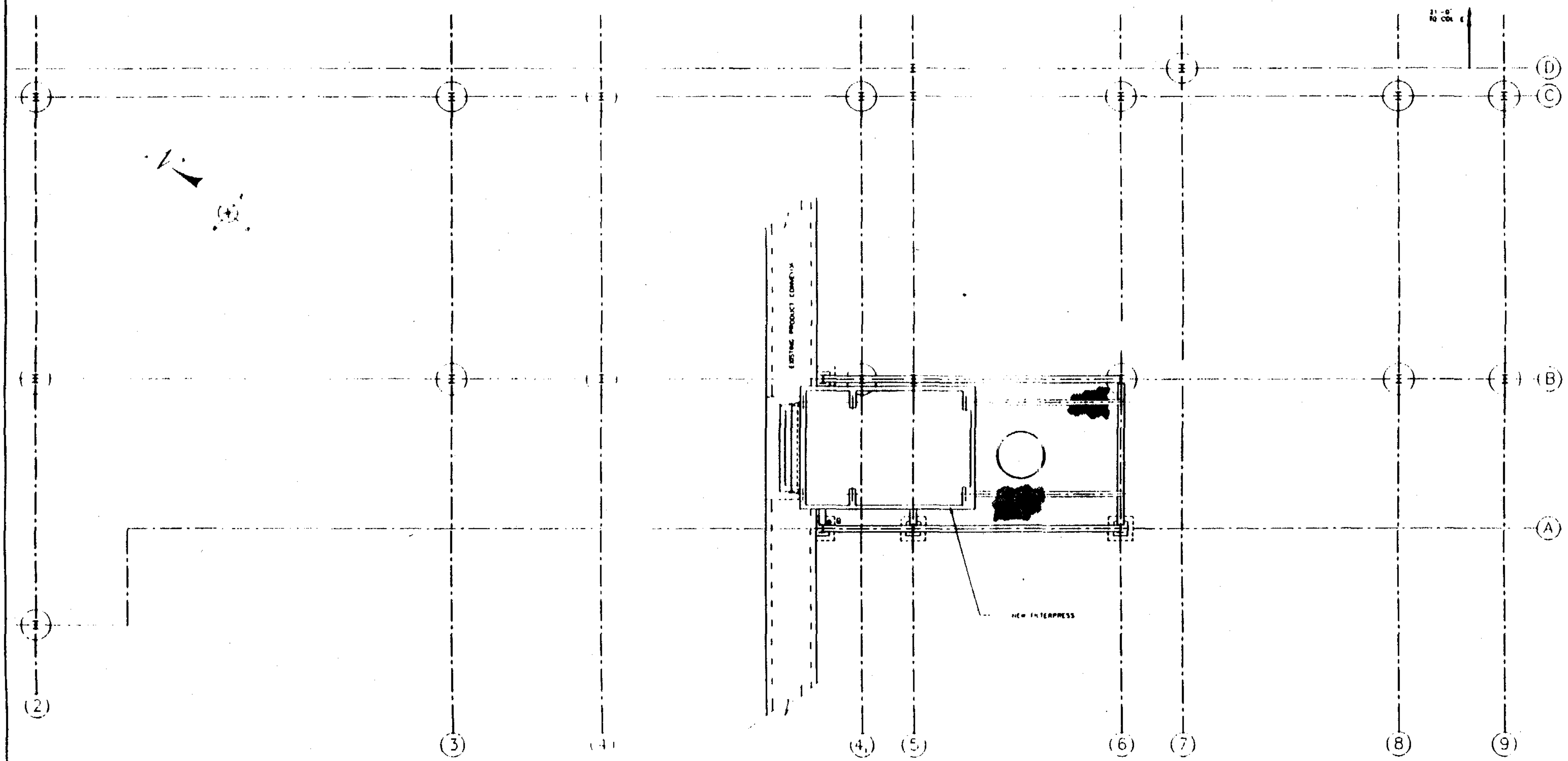
UNLESS OTHERWISE SPECIFIED

USED ON

DRAWN RWL | DATE 04-20-94 | ENGINEER

TITLE TWR THICKENER UNDERFLOW CONVERSION (TUC)
THICKENER TANK UDERFLOW PIPING
PLAN VIEW

SIZE	DRAWING NUMBER	SHEET	REV
D	P-170-04	1	0



ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

TECOGEN
45 FIRST AVENUE WALTHAM,MA 02254-9046

UNLESS OTHERWISE SPECIFIED

SCALE 1/8" = 1'-0"
MATERIAL
FINISH
NO REQUIRED
NEXT ASSEMBLY
ISSUE DATE 3/20/94
SIMILAR TO

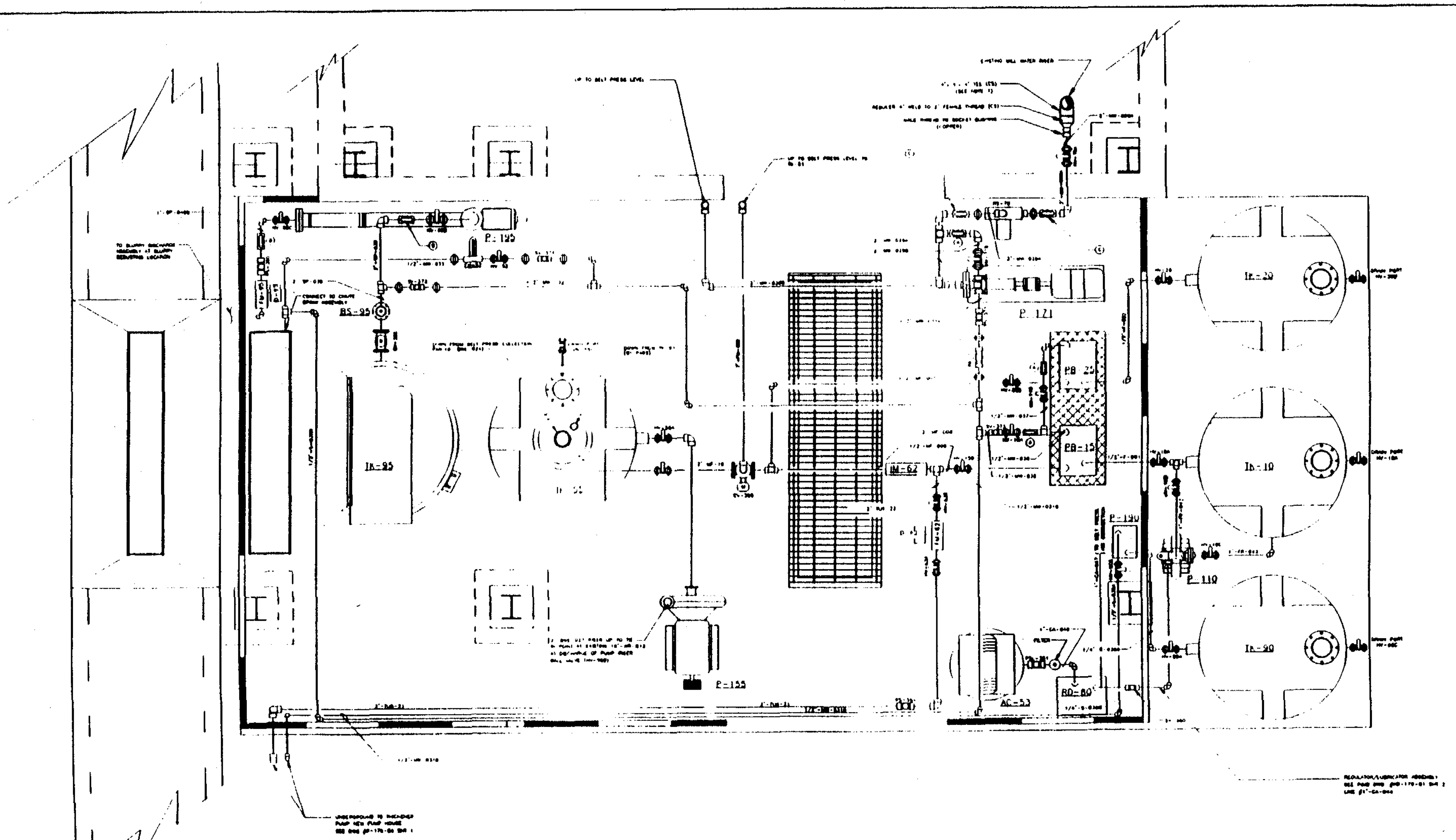
USED ON

DRAWN RWL
DATE 04-21-94
CHECKED

TITLE TWR THICKENER UNDERFLOW CONVERSION (TUC) BELTPRESS PIPING
PLAN VIEW

SIZE D
DRAWING NUMBER P-170-04
SHEET 2
REV 0

REV	DESCRIPTION	DATE	BY	APPR
1				



ID	INSTRUMENT	DESCRIPTION
Ⓐ	PRESSURE GA	0 - 100 PSI
Ⓑ	PRESSURE GA	0 - 150 PSI
Ⓒ	PRESSURE GA	0 - 250 PSI

REV	DESCRIPTION	DATE	BY	APPR
2	SURFACANT LINE S-0388/ADDED DRAIN LINES TO TK-10, 20 & 90	12/27/94	RWL	
1	MOVED FRONT WALL, EQUIP. AND PIPING FORWARD	11/14/94	RWL	

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

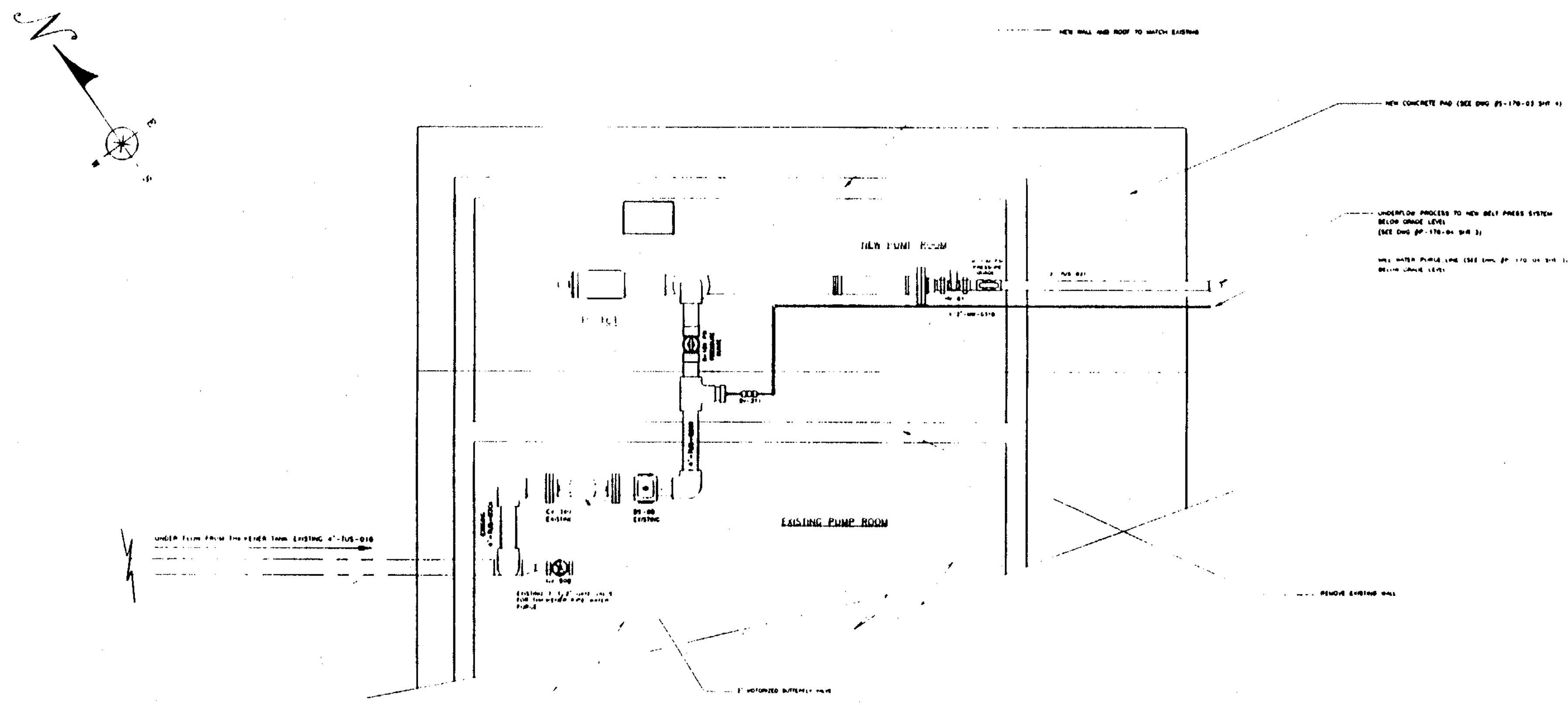
SCALE 3/4" = 1'-0"

UNLESS OTHERWISE SPECIFIED

DRAWN: RWL — DATE: 07-24-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) GRADE LEVEL PIPING LAYOUT PLAN VIEW

SIZE: D — DRAWING NUMBER: P-170-04 — SHEET: 3 — REV: 2



REF. P&ID DWG PD-170-01 SHT 2

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE 3/4" = 1'-0"

TECOGEN
45 FIRST AVENUE WALTHAM, MA 02254-9046

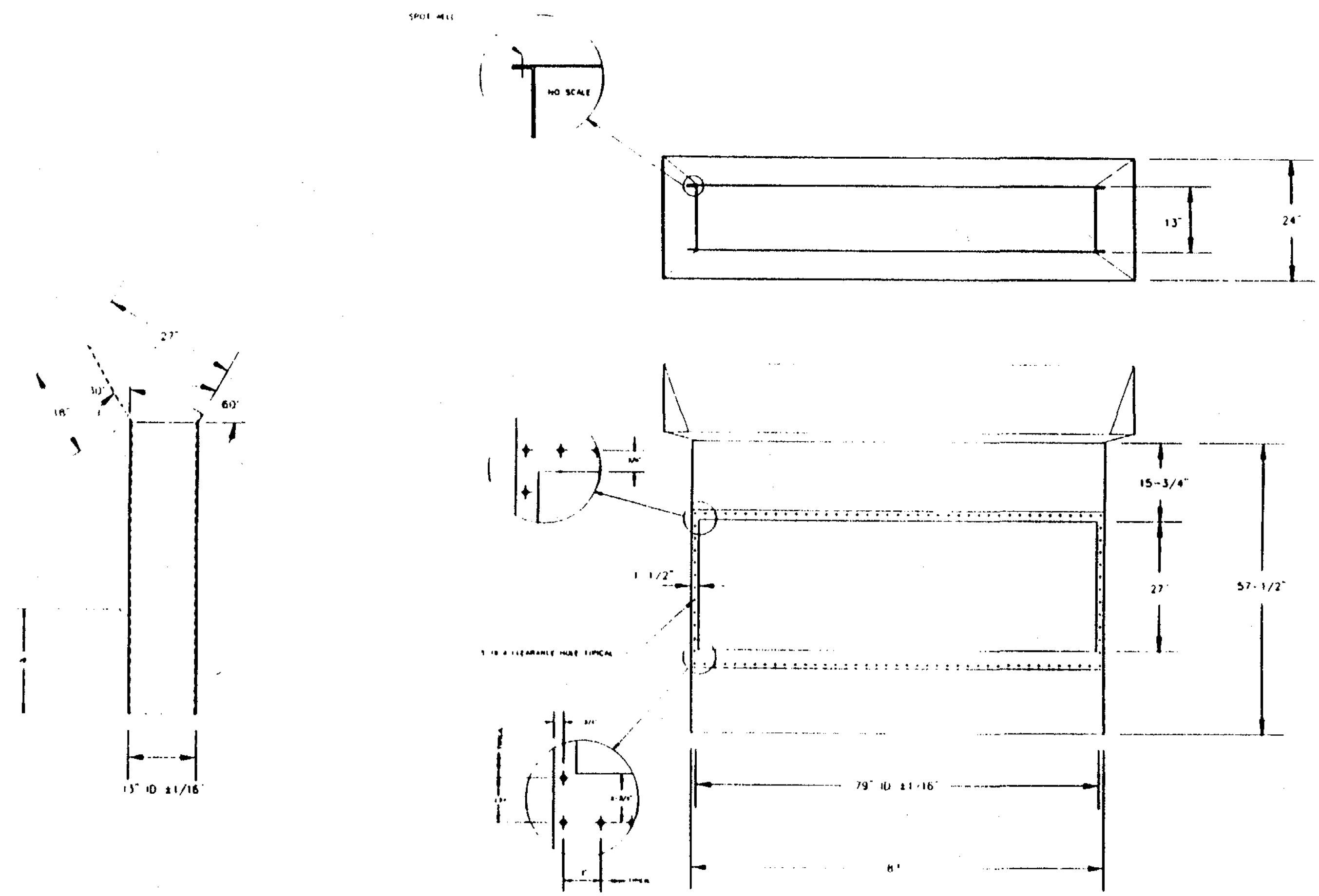
UNLESS OTHERWISE SPECIFIED

DRAWN: RWL | DATE: 12-21-94 | ENGINEER:

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC)
THICKENER PUMP RM EQUIP & PIPING
PLAN VIEW

SIZE: D | DRAWING NUMBER: P-170-04 | SHEET: 4 | REV: 0

REV	DESCRIPTION	DATE	BY	APPR
1				



MAIN SECTION

NOTES.

1) MATERIAL HOT ROLLED CARBON STEEL
2) 11ga

REV	DESCRIPTION	DATE	BY	APPR
1				

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE: NOTED

TECOGEN
45 FIRST AVENUE WALTHAM,MA 02254-9046

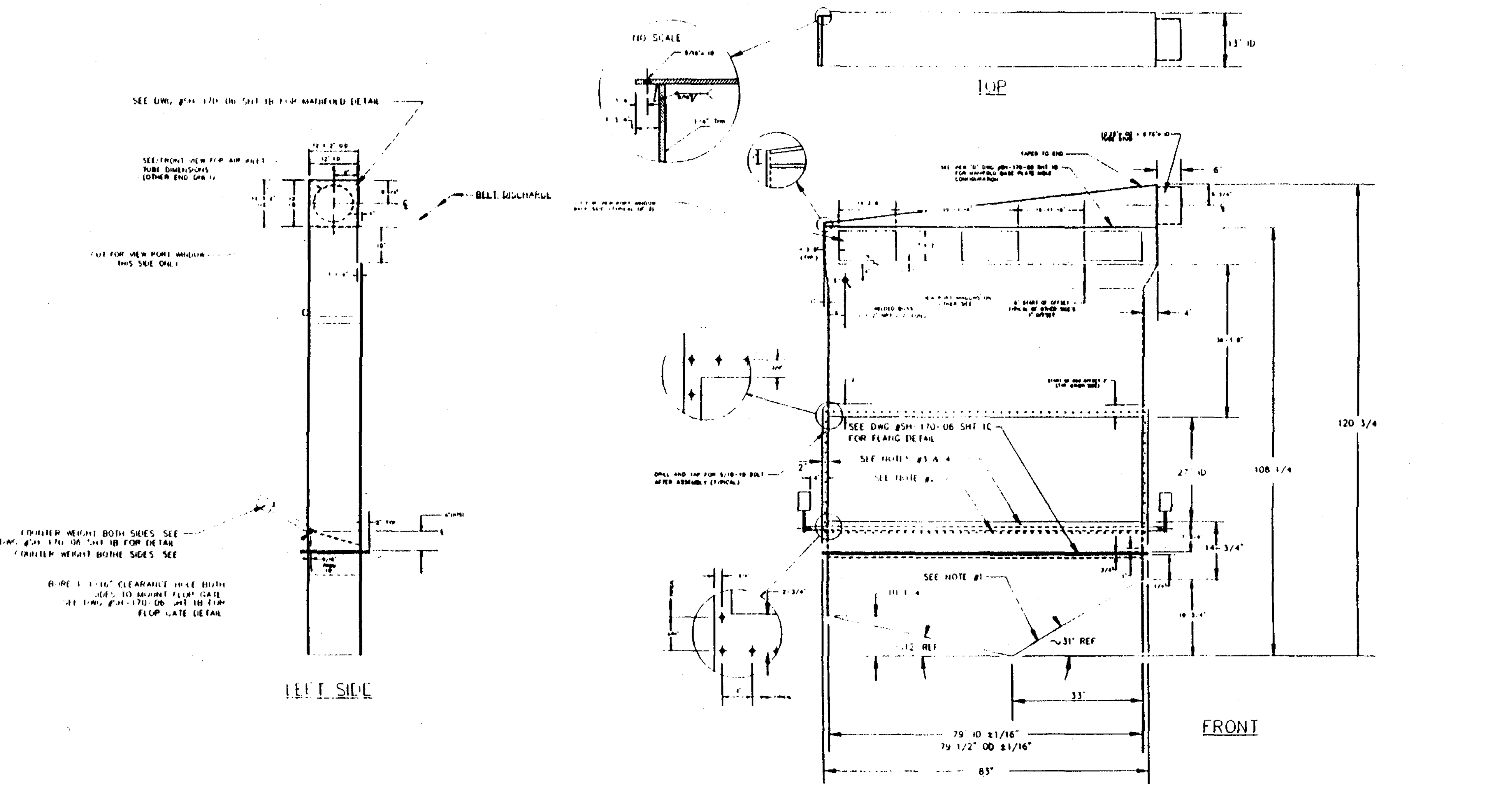
UNLESS OTHERWISE SPECIFIED

DRAWN: RML DATE: 09-26-94

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
BELT PRESS DIVERTER CHUTE
MAIN SECTION

ISSUE DATE 5/20/94

SIZE: D DRAWING NUMBER: SH-170-06 SHEET: 1 REV: 0



NOTES:

1) INSERT 1" BELOW PRODUCT CONVEYOR'S COVER PLATE (BOTTOM TO FIT CONTOUR OF EXISTING CONVEYOR COVER PLATE) FIELD WELD ALL AROUND
2) USE 5/16-18 x 1/2" LONG BOLT WITH LOCK WASHER (TYP.)
3) SEAL BETWEEN DIVERTER CHUTE AND MAIN CHUTE WITH RTV
4) INCREASE HOLE DIAMETER ON DIVERTER CHUTE'S MATING FLANGE TO 3/8" Ø CLEARANCE HOLE

REV	DESCRIPTION	DATE	BY	APPR
2	MOVE FLOP GATE UP 2"	04-11-95	RWL	
1	THROUGH OUT	03-07-95	RWL	

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

TECOGEN
45 FIRST AVENUE WALTHAM, MA 02254-9046

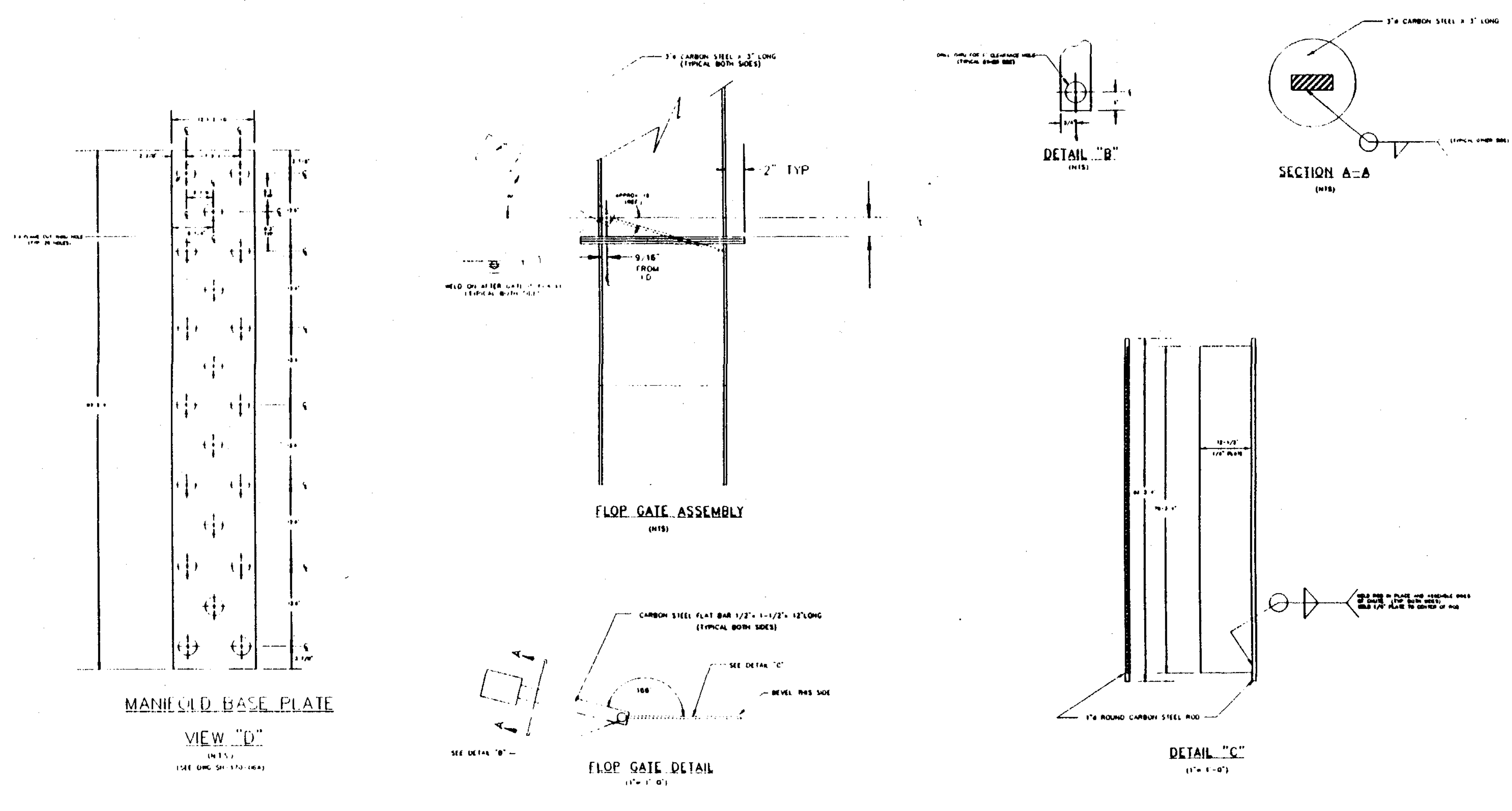
SCALE: 1" = 1'-0"
MATERIAL: 1/4" CARBON STL
FINISH:
NO REQUIRED:
NEXT ASSEMBLY:
ISSUE DATE:
SIMILAR TO:

UNLESS OTHERWISE SPECIFIED

USED ON | DRAWN: RWL | DATE: 02-20-95 | ENGINEER:

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
BELT PRESS DIVERTER CHUTE
NEW MAIN SECTION

SIZE: D | DRAWING NUMBER: SH-170-06 | SHEET: 1A | REV: 2



TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

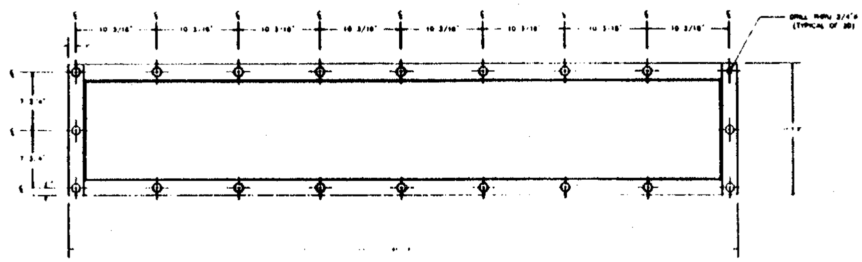
REV	DESCRIPTION	DATE	BY	APPR
1	MANIFOLD BASE PLATE & FLOP GATE ASSEMBLY	03-07-95	RWL	

SCALE: NOTED

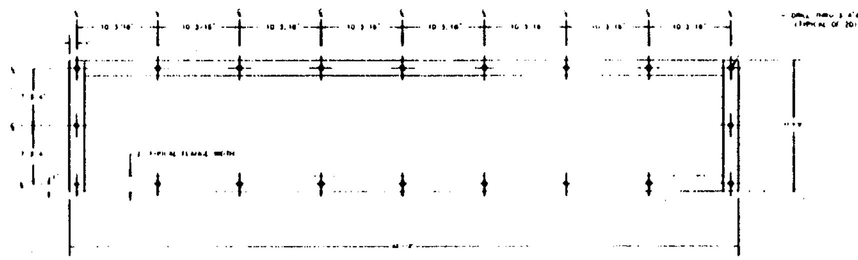
DRAWN: RWL — DATE: 02-20-95

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
BELT PRESS DIVERTER CHUTE
NEW MAIN SECTION DETAILS

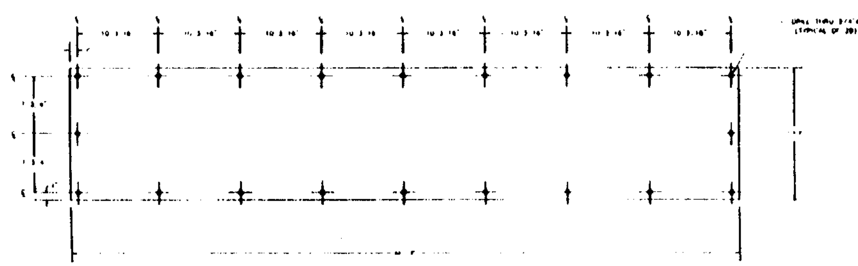
SIZE: D — DRAWING NUMBER: SH-170-06 — SHEET: 18 — REV: 1



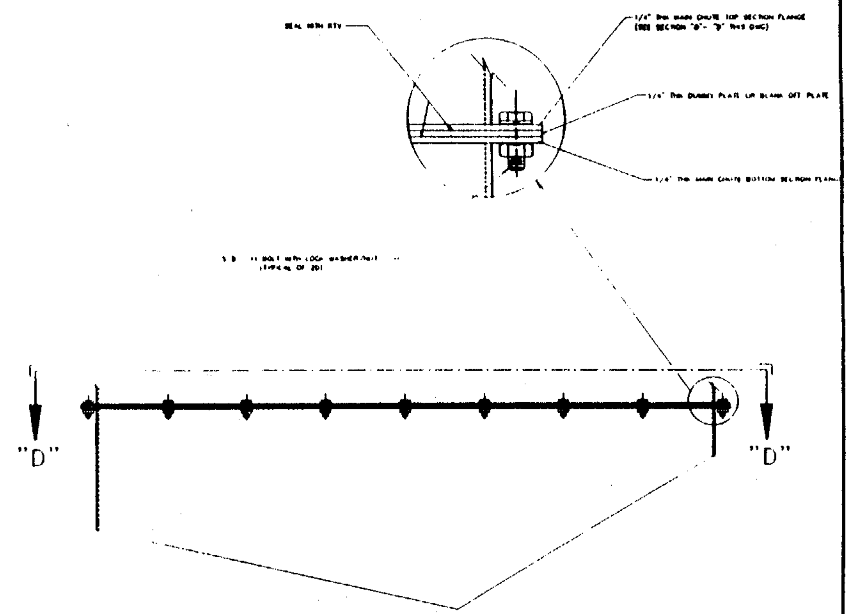
SECTION "D"-"D"



MAIN DUMMY PLATE



BLANK (BLIND) PLATE



MAIN CHUTE BOTTOM SECTION

REV	DESCRIPTION	DATE	BY	APPR
1				

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REV NO

SCALE: 1-1/2" = 1'-0"

MATERIAL: 1/4" CARBON ST. UNLESS NOTED

FINISH

NO REQUIRED

NEXT ASSEMBLY

ISSUE DATE

SIMILAR TO

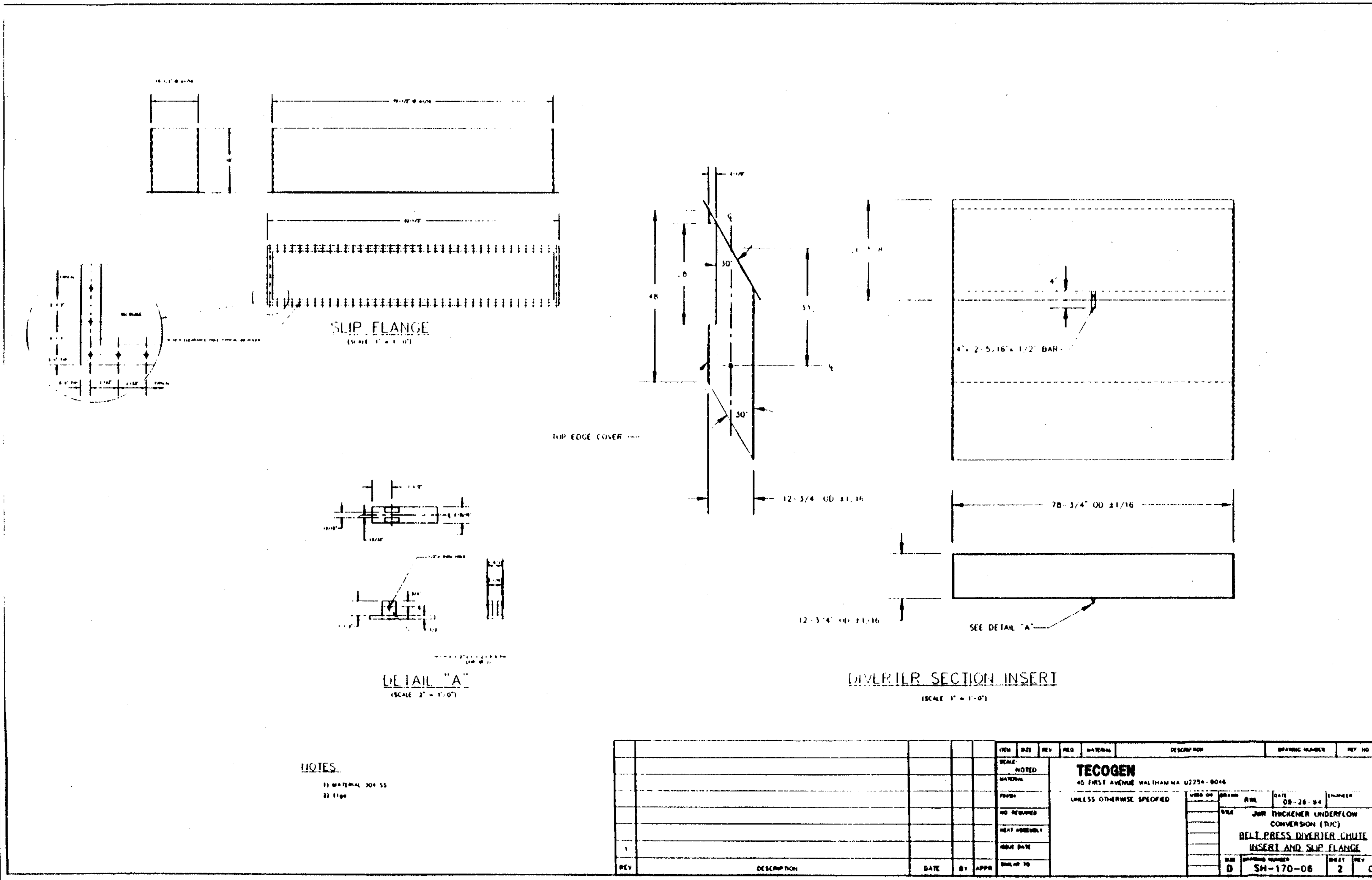
TECOGEN
45 FIRST AVENUE WALTHAM,MA 02254-9046

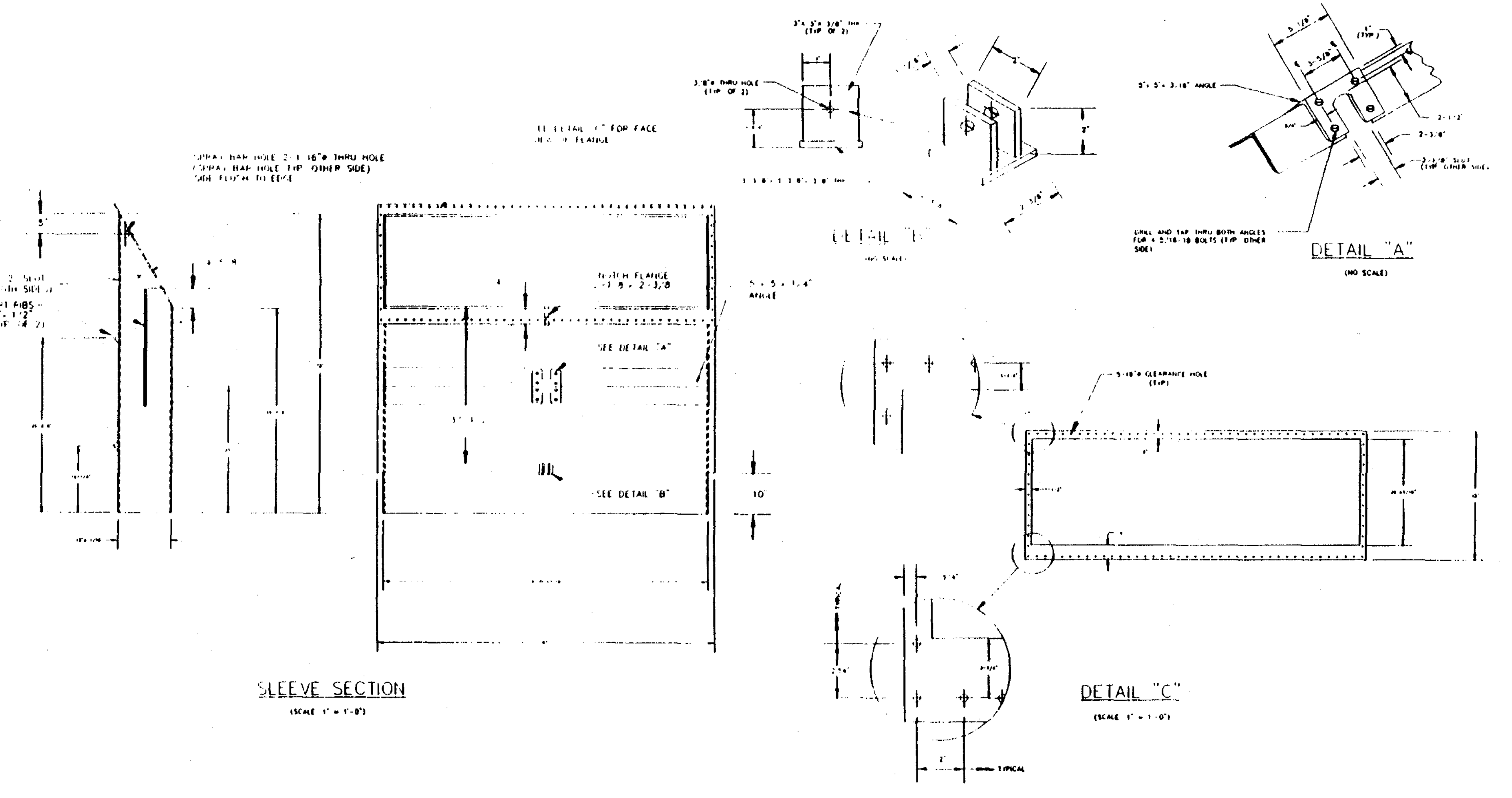
UNLESS OTHERWISE SPECIFIED

USED ON | DRAWN: RWL | DATE: 03-01-95 | ENGINEER

TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC)
BELT PRESS DIVERTER CHUTE
NEW MAIN BOTTOM SECTION

SIZE: D | DRAWING NUMBER: SH-170-06 | SHEET: 1C | REV: 0


SLIP FLANGE
(SCALE 1" = 1'-0")
TOP EDGE COVER
12-3/4" OD ±1/16
30°
48
4" x 2-5/16" x 1/2" BAR
78-3/4" OD ±1/16
12-3/4" OD ±1/16
SEE DETAIL "A"
DETAIL "A"
(SCALE 2" = 1'-0")
DIVERTER SECTION INSERT
(SCALE 1" = 1'-0")
NOTES:
1) MATERIAL 304 SS
REV
DESCRIPTION
DATE
BY
APPR
ITEM
SIZE
REV
REQ
MATERIAL
DESCRIPTION
DRAWING NUMBER
REV NO
SCALE: NOTED
MATERIAL
FINISH
NO REQUIRED
NEXT ASSEMBLY
ISSUE DATE
SIMILAR TO
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046
UNLESS OTHERWISE SPECIFIED
DRAWN RML
DATE 08-26-94
TITLE
JWR THICKENER UNDERFLOW CONVERSION (TUC)
BELT PRESS DIVERTER CHUTE INSERT AND SLIP FLANGE
SIZE D
DRAWING NUMBER SH-170-06
SHEET 2
REV 0

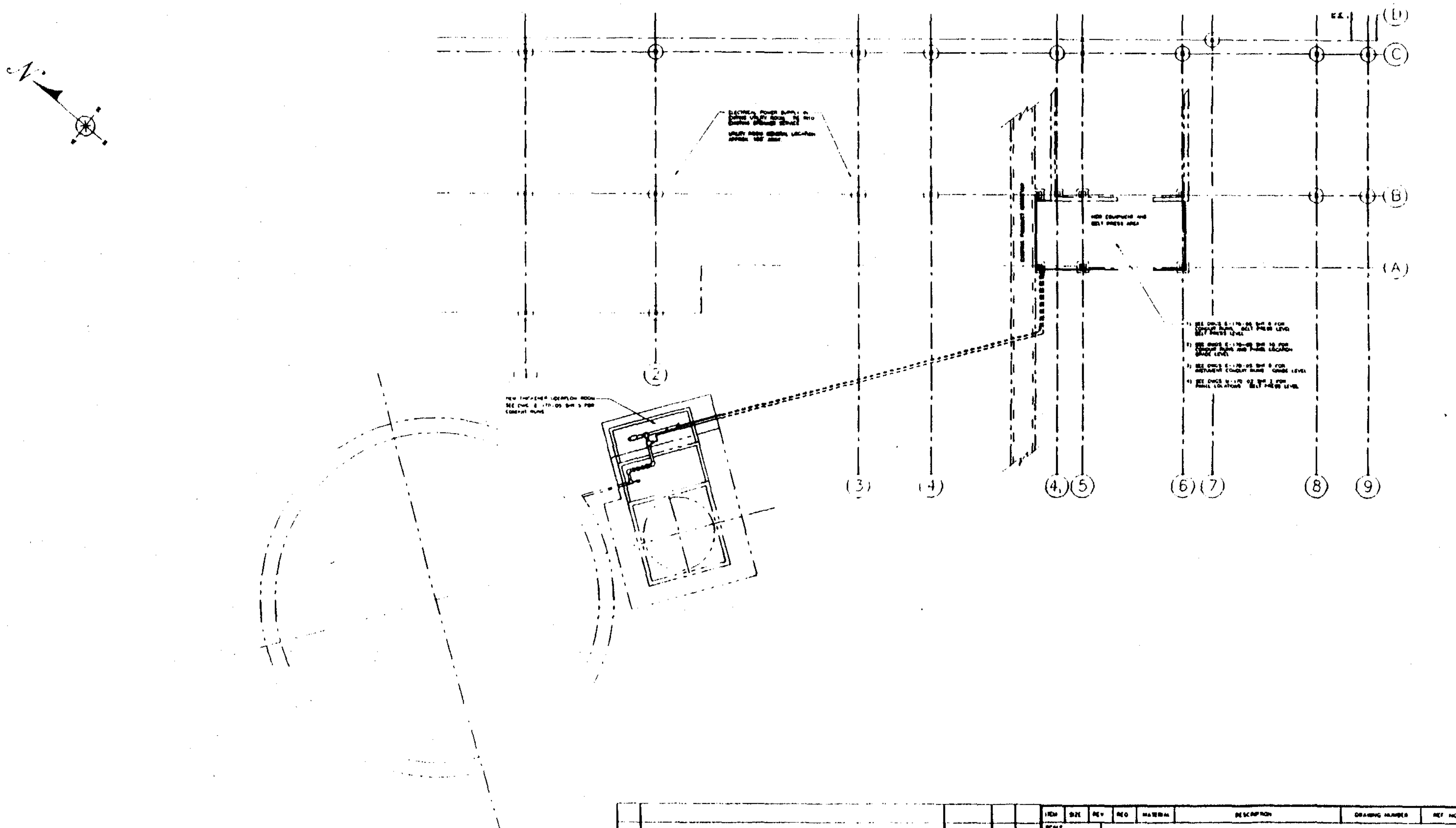


NOTES:

1) MATERIAL 304 SS

SCALE: NOTED	**TECOGEN** 45 FIRST AVENUE WALTHAM, MA 02254-9046							
MATERIAL	UNLESS OTHERWISE SPECIFIED	USED ON	DRAWN: RWL	DATE: 10-05-94	ENGINEER			
FINISH			TITLE: JWR THICKENER UNDERFLOW CONVERSION (TUC) BELT PRESS DIVERTER CHUTE SECTION SLEEVE					
NO. REQUIRED								
NEXT ASSEMBLY								
ISSUE DATE 9/20/94			SIZE: D	DRAWING NUMBER: SH-170-06	SHEET: 3	REV: 0		

A3 - ELECTRICAL INSTALLATION DRAWINGS



ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE 1/8" = 1'-0"

TECOGEN

45 FIRST AVENUE WALTHAM MA 02254-9046

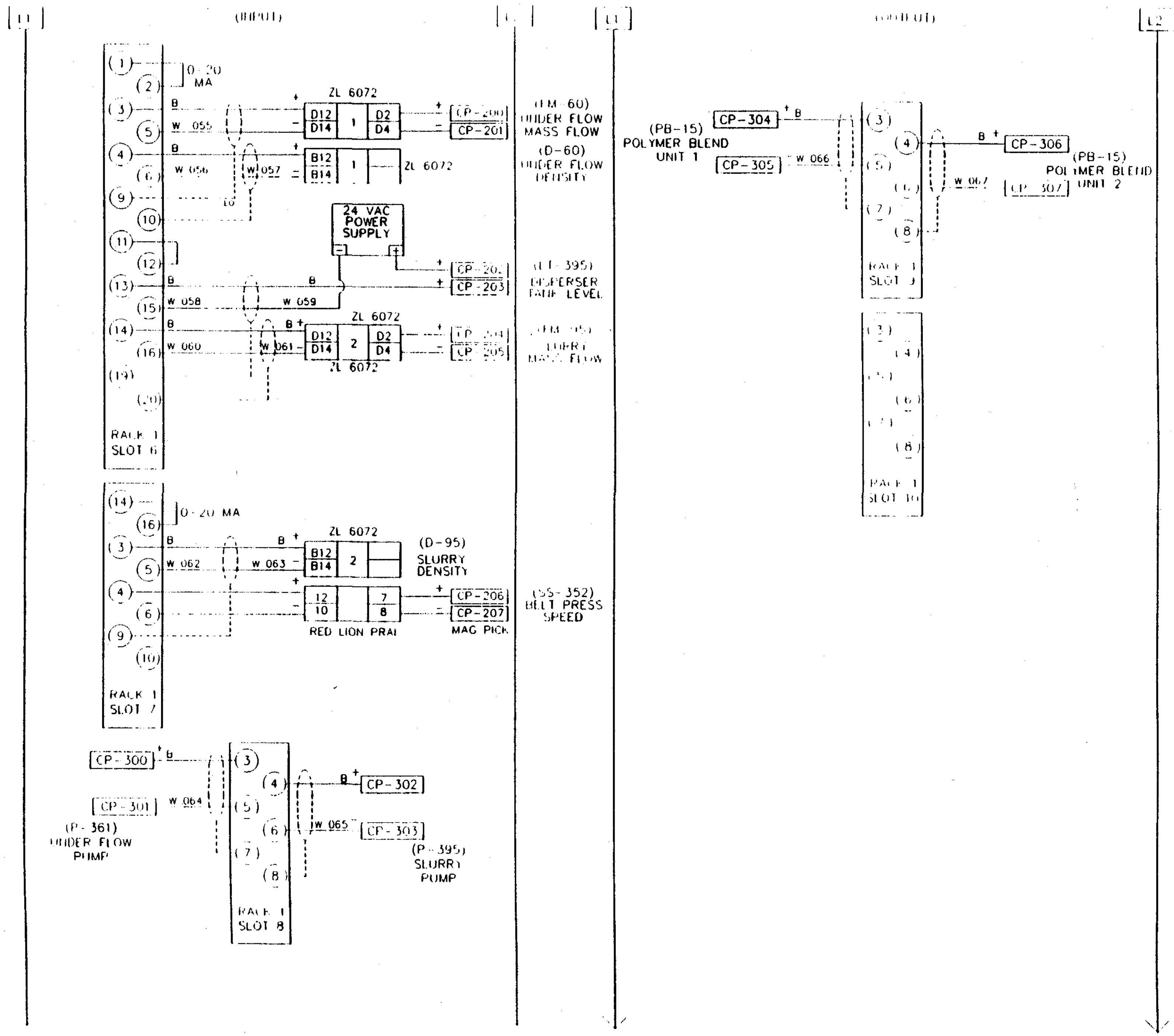
UNLESS OTHERWISE SPECIFIED

DRAWN RWL — DATE 12/02/94 — ENGINEER

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) THICKENER UNDERFLOW SITE PLAN ELECTRICAL

SIZE	DRAWING NUMBER	SHEET	REV
D	P-170-05	12	0

REV	DESCRIPTION	DATE	BY	APPR
1				



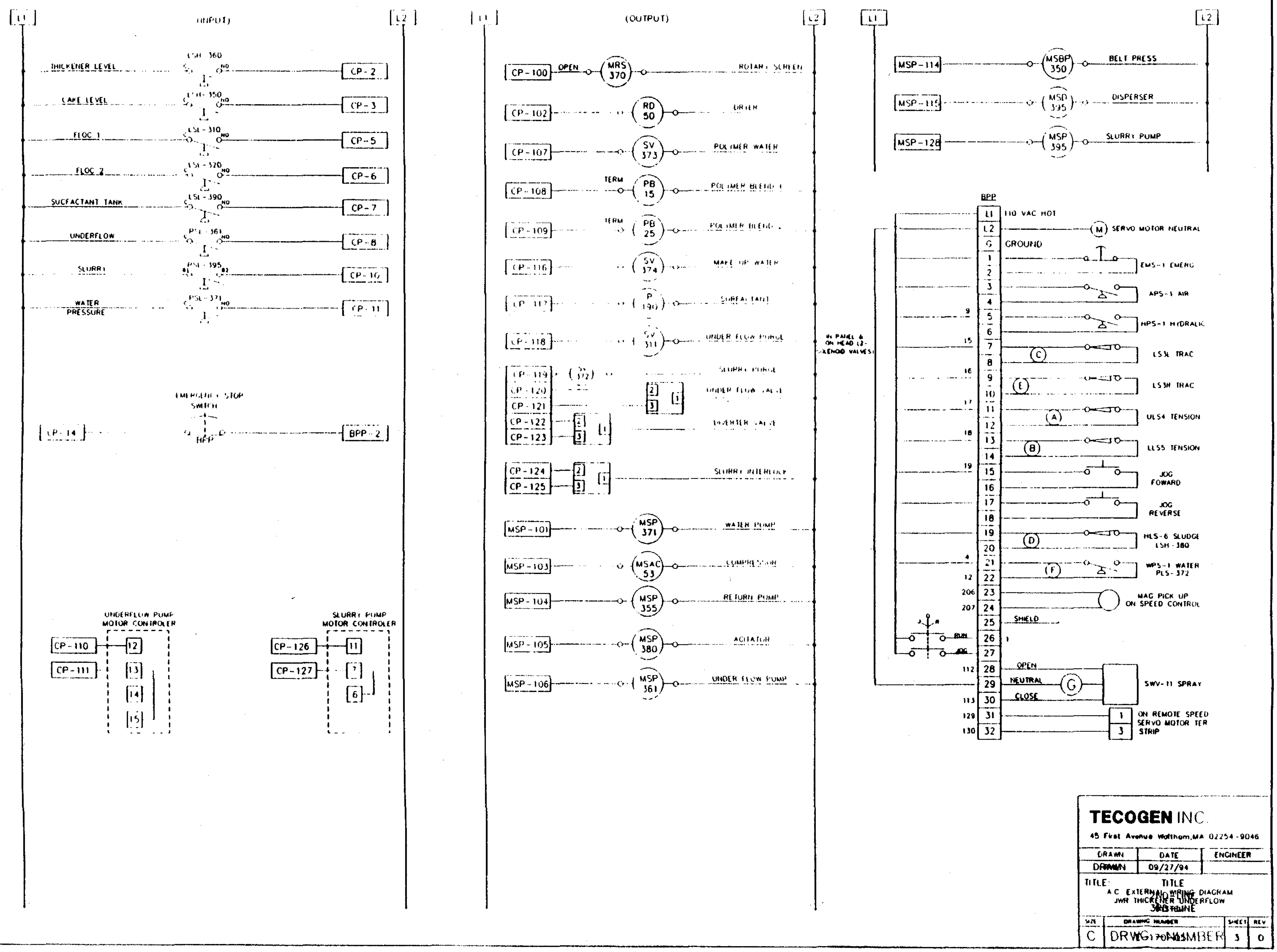
TECOGEN INC.

45 First Avenue Waltham, MA 02254-9046

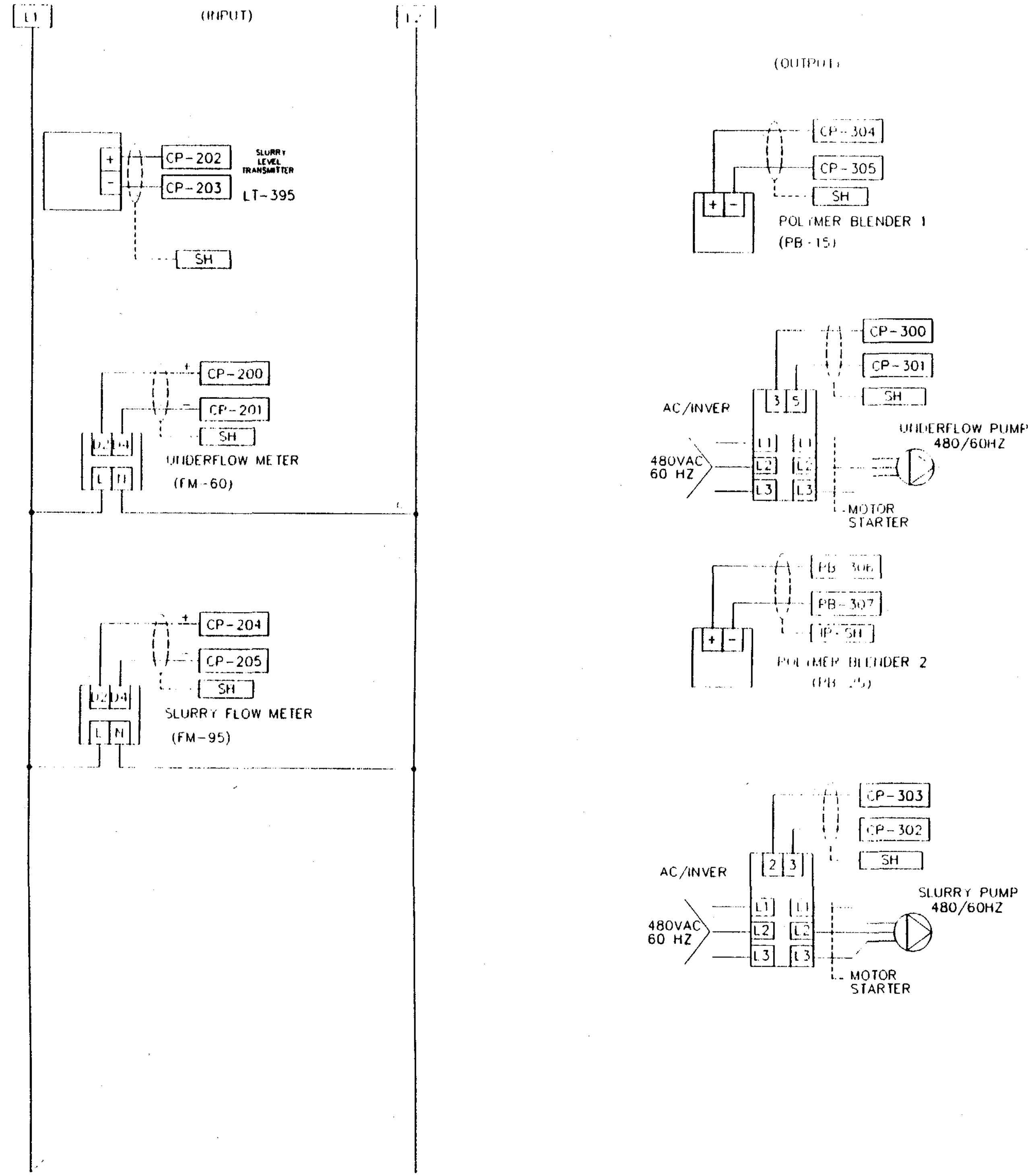
DRAWN	DATE	ENGINEER
DRAWN	09/12/94	

TITLE: D.C. INTERNAL WIRING DIAGRAM JWR THICKENER UNDERFLOW 3RD-LINE

SIZE	DRAWING NUMBER	SHEET	REV
C	DRWG NUMBER	2	0



(INPUT)
THICKENER LEVEL
CAKE LEVEL
FLOC 1
FLOC 2
SUCFACTANT TANK
UNDERFLOW
SLURRY
WATER PRESSURE
LSL-310
LSL-320
LSL-390
CP-2
CP-3
CP-5
CP-6
CP-7
CP-8
CP-10
CP-11
EMERGENCY STOP SWITCH
BPP-2
UNDERFLOW PUMP MOTOR CONTROLER
SLURRY PUMP MOTOR CONTROLER
CP-110
CP-111
CP-126
CP-127
(OUTPUT)
CP-100
OPEN
MRS 370
ROTARY SCREEN
CP-102
RD 50
DRYER
CP-107
SV 373
POLYMER WATER
CP-108
TERM
PB 15
CP-109
PB 25
CP-116
SV 374
MAKE UP WATER
CP-118
UNDER FLOW PURGE
CP-119
CP-121
CP-122
CP-123
SLURRY PURGE
CP-124
CP-125
SLURRY INTERLOCK
MSP-101
MSP 371
WATER PUMP
MSP-103
MSAC 53
MSP-104
MSP 355
RETURN PUMP
MSP-105
MSP 380
AGITATOR
MSP-106
MSP 361
UNDER FLOW PUMP
MSP-114
MSBP 350
BELT PRESS
MSP-128
MSP 395
SLURRY PUMP
BPP
110 VAC HOT
SERVO MOTOR NEUTRAL
GROUND
EMS-1 EMERG
APS-1 AIR
HPS-1 HYDRALIC
LS3L TRAC
LS3R TRAC
ULS4 TENSION
LLS5 TENSION
JOG FOWARD
JOG REVERSE
HLS-6 SLUDGE LSH-380
WPS-1 WATER PLS-372
MAG PICK UP ON SPEED CONTROL
SHIELD
RUN
JOG
OPEN
NEUTRAL
CLOSE
SWV-11 SPRAY
ON REMOTE SPEED SERVO MOTOR TER STRIP
TECOGEN INC.
45 First Avenue Waltham, MA 02254-9046
DRAWN
DATE
ENGINEER
09/27/94
TITLE
A C EXTERNAL WIRING DIAGRAM
JWR THICKENER UNDERFLOW
SIZE
DRAWING NUMBER
SHEET
REV
C
3
0



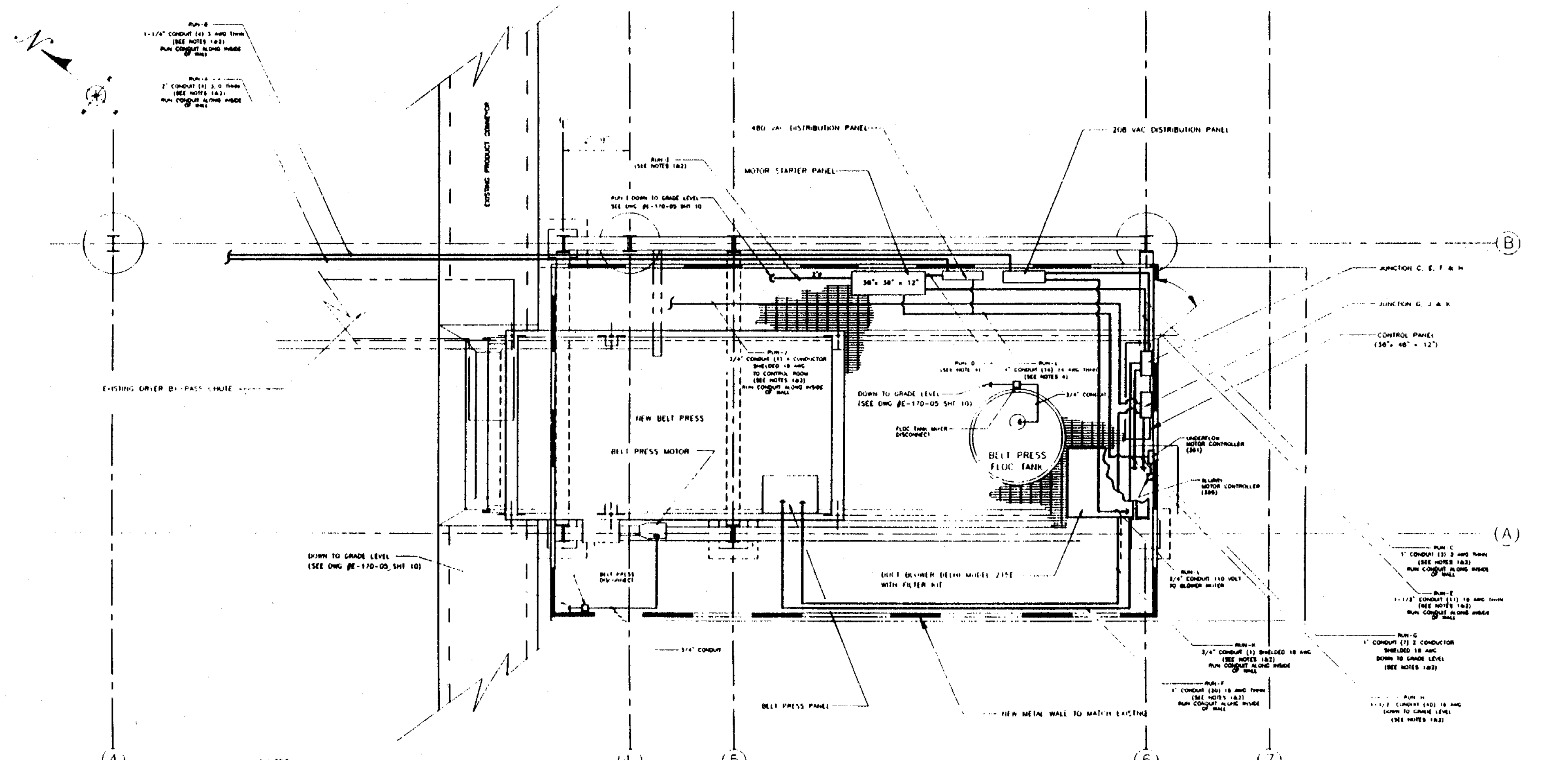
TECOGEN INC

45 First Avenue Waltham, MA 02254-9046

DRAWN	DATE	ENGINEER
DRAWN	10-18-94	

TITLE: TITLE
D.C. EXTERNAL WIRING DIAGRAM
JWR THICKENER UNDERFLOW
3RD LINE

SIZE	DRAWING NUMBER	SHEET	REV
C	DRWG NUMBER	5	0



NOTES

1) CONDUIT AND FITTINGS TO BE SUPPLIED BY CONTRACTOR
2) SEE INTERCONNECTION LIST FOR DESIGNATION POINTS
3) USE WIRE TROUGH WITH ACCESS PANEL, 12" LONG
4) ELECTRICAL CONTRACTOR RESPONSIBLE FOR CONDUIT BENDS, JUNCTION BOXES, FLEX CONNECTIONS, RACEWAYS AND HANGERS
5) ALL CONNECTIONS MUST MEET NEC REQUIREMENTS
6) WHEN CONDUIT SIZE IS NOT SPECIFIED USE 3/4"
7) UNLESS SPECIFIED USE 18 AWG THHN WIRE
8) WHERE POSSIBLE, ALL HORIZONTAL CONDUIT RUNS AND RACEWAYS TO RUN AT A APPROXIMATE ELEVATION OF 618' ABOVE SEA LEVEL

REV	DESCRIPTION	DATE	BY	APPR
1	AS PER DESIGN MEETING #1 (10-27-94) SEE MEETING MINUTES #1	11/07/94	RWL	

170-30-1

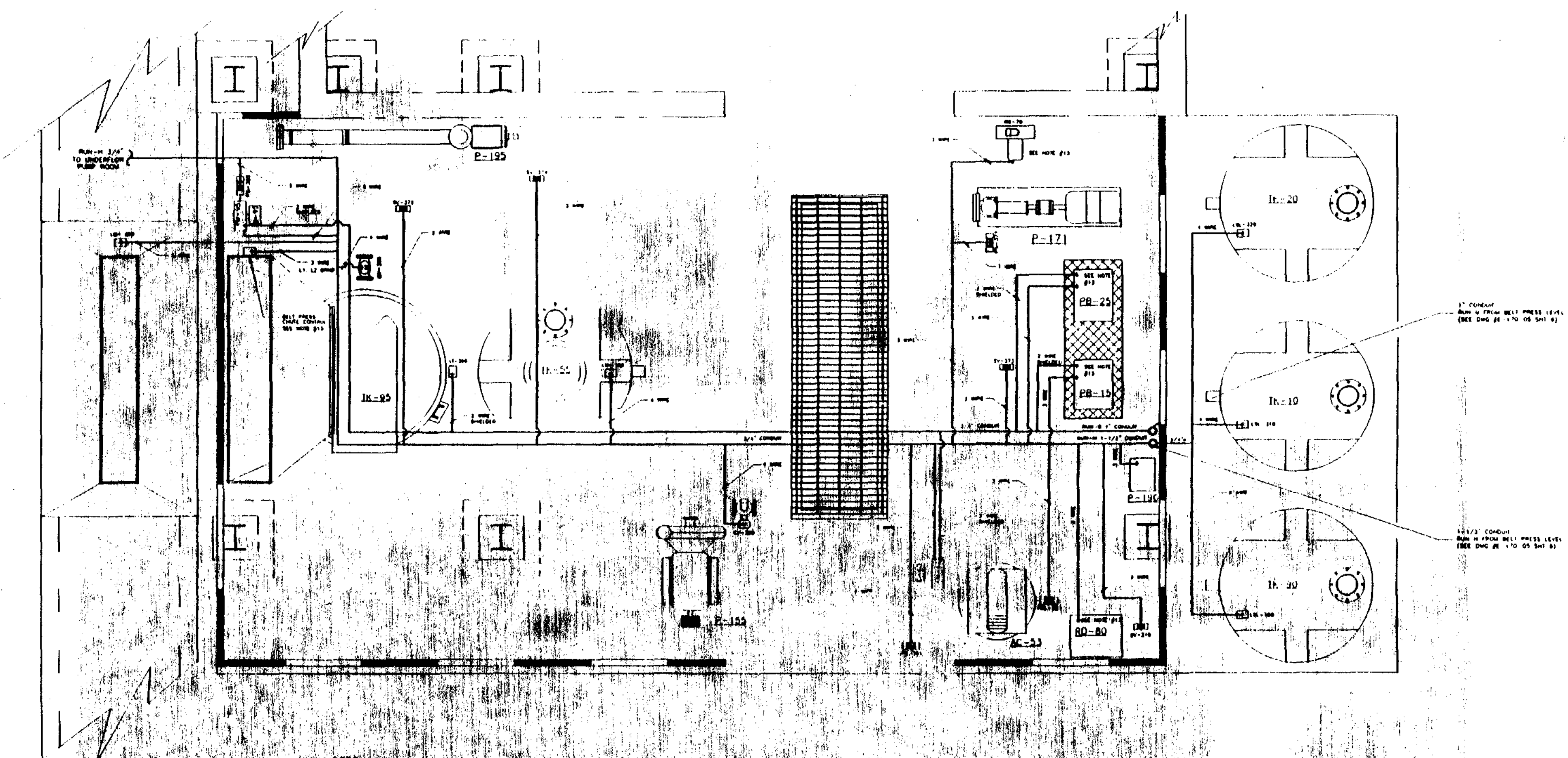
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

SCALE 1/2" = 1'-0"
ISSUE DATE 5/20/94
DRAWN RWL | DATE 10-18-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC)
ELECTRICAL CONDUIT & PANEL LOCATION
BELT PRESS LEVEL PLAN

SIZE D | DRAWING NUMBER E-170-05 | SHEET 6 | REV 1



NOTES:

1) UNLESS SPECIFIED, A SINGLE L1 & L2 AND GROUND CAN FEED ALL COMPONENTS
2) SEE INTERCONNECTION LIST FOR DESIGNATION POINTS
3) ALL SOLENOID VALVES (SV) REQUIRE SIGNAL, L2 AND GROUND WIRES
4) ALL PRESSURE SWITCHES (PS) REQUIRE L1, SIGNAL AND GROUND WIRES
5) ELECTRICAL CONTRACTOR RESPONSIBLE FOR CONDUIT, FITTINGS, BENDS, JUNCTION BOXES, FLEX CONNECTIONS, RACEWAYS AND HANGERS.
6) UNLESS SPECIFIED USE 14 AWG THHN WIRE
7) ALL CONNECTIONS MUST MEET NEC REQUIREMENTS
8) UNLESS SPECIFIED, CONDUIT IS 3/4"
9) UNLESS SPECIFIED USE 16 AWG [illegible] WIRE
10) WHERE POSSIBLE, ALL HORIZONTAL CONDUIT RUNS AND RACEWAYS TO RUN AT A APPROXIMATE ELEVATION OF 618' ABOVE SEA LEVEL
11) ALL LEVEL SWITCHES (LS) US L1, L2, SIGNAL AND GROUND
12) ALL CONTROL VALVES (CV) USE SIGNAL, SIGNAL, L2 AND GROUND
13) USE SEPERATE L2 & GROUND WIRES FROM PANEL

REV	DESCRIPTION	DATE	BY	APPR
1				

SCALE: 3/4" = 1'-0"
MATERIAL
FINISH
NO REQUIRED
NEXT ASSEMBLY
ISSUE DATE
SIMILAR TO

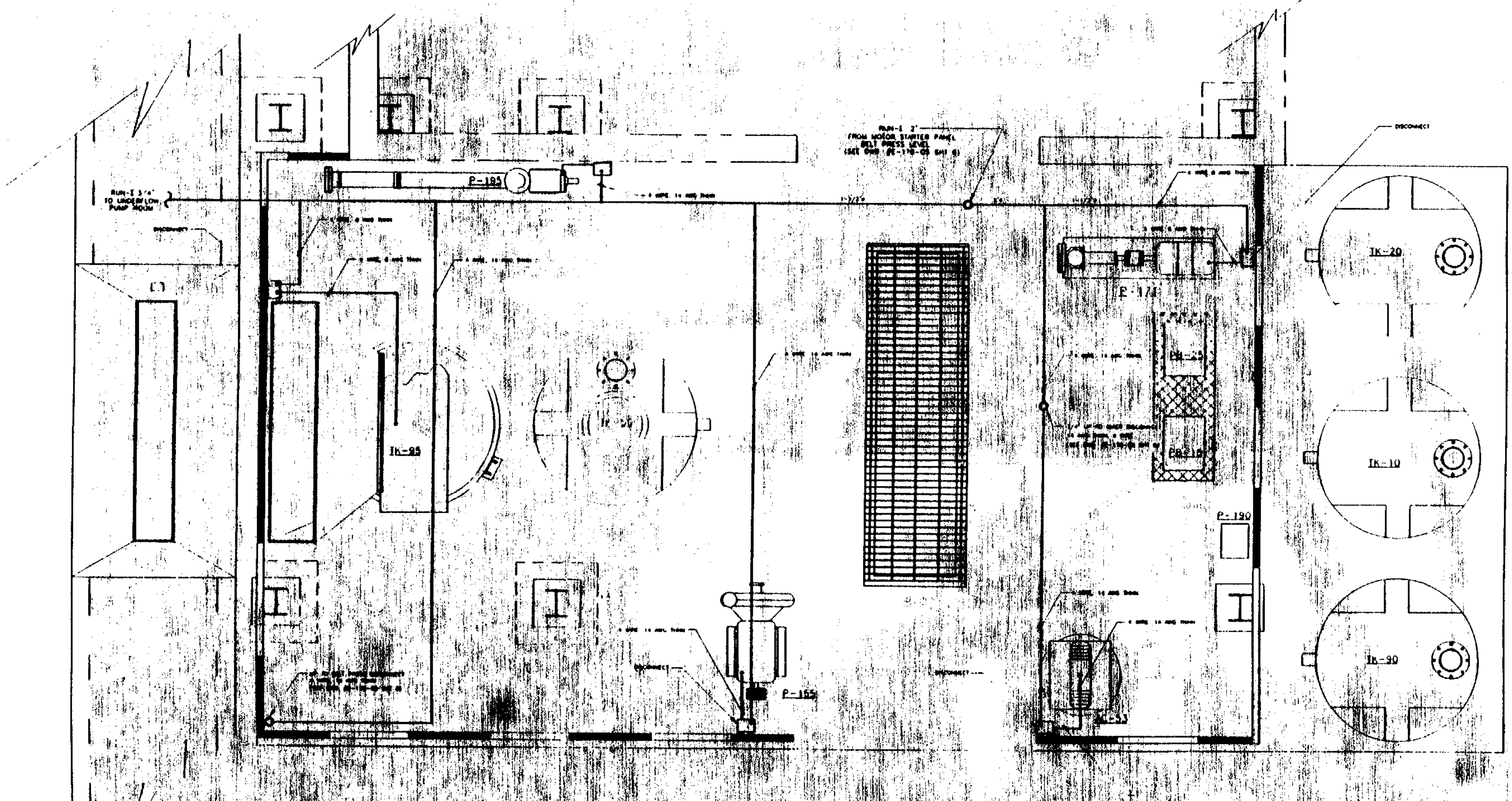
TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

DRAWN: RWL | DATE: 11-08-94 | ENGINEER

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) GRADE LEVEL INSTRUMENT CONDUIT RUN
PLAN VIEW

SIZE: D | DRAWING NUMBER: E-170-05 | SHEET: 9 | REV: 0



NOTES:

1) CONDUIT AND FITTINGS TO BE SUPPLIED BY CONTRACTOR
2) SEE INTERCONNECTION LIST FOR DESIGNATION POINTS
3) USE WIRE TROUGH WITH ACCESS PANEL, 18" LONG
4) ELECTRICAL CONTRACTOR RESPONSIBLE FOR CONDUIT, BENDS, JUNCTION BOXES, FLEX CONNECTIONS, RACEWAYS AND HANGERS
5) ALL CONNECTIONS TO MOTORS MUST PASS THRU A DISCONNECT AND FOLLOW ALL NEC REQUIREMENTS
6) WHEN CONDUIT SIZE IS NOT SPECIFIED USE 3/4"
7) UNLESS SPECIFIED USE 16 AWG THHN WIRE
8) WHERE POSSIBLE, ALL HORIZONTAL CONDUIT RUNS AND RACEWAYS TO RUN AT A APPROXIMATE ELEVATION OF 618' ABOVE SEA LEVEL

REV	DESCRIPTION	DATE	BY	APPR
1				

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

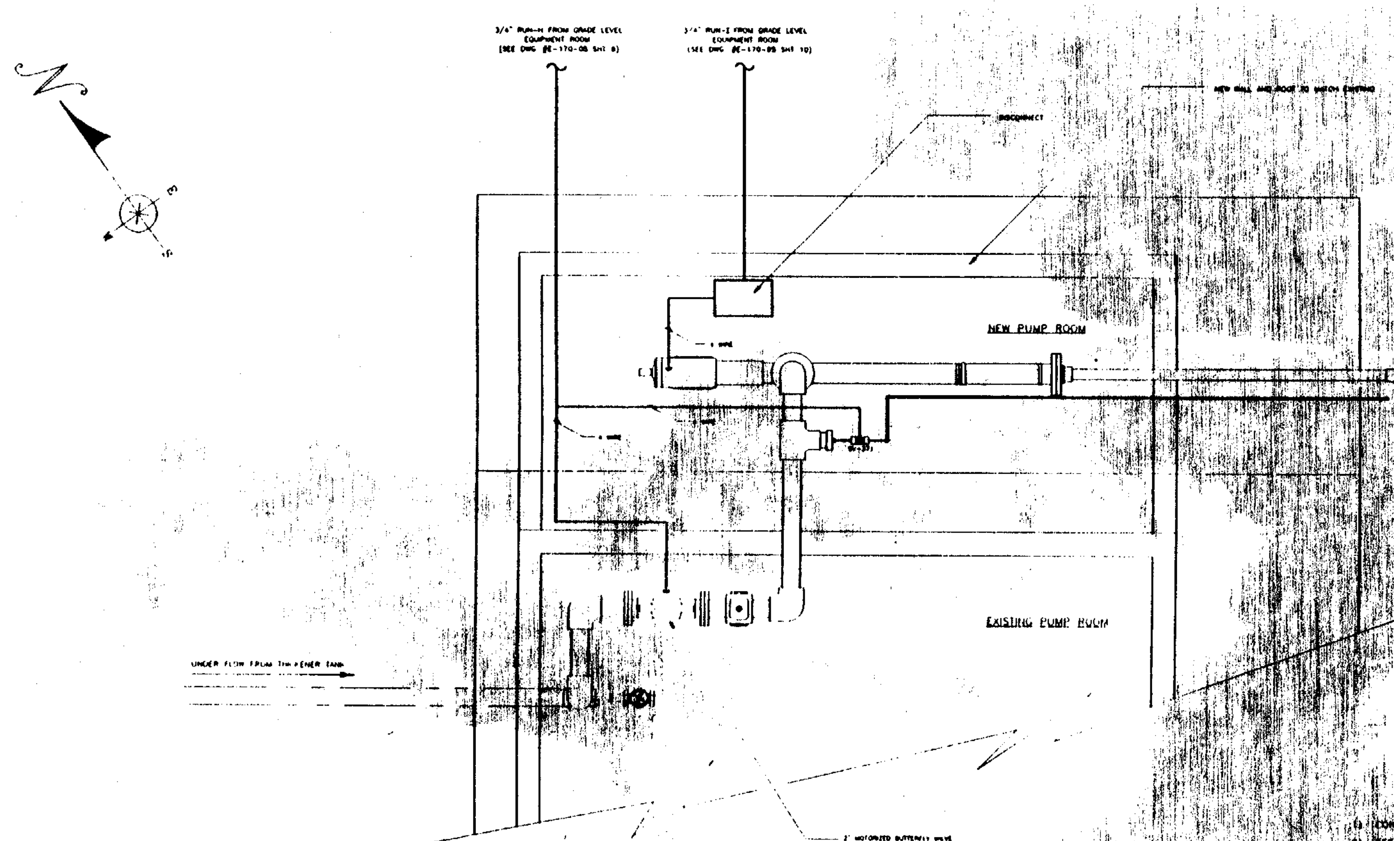
UNLESS OTHERWISE SPECIFIED

SCALE 3/4" = 1'-0"

DRAWN RWL | DATE 11-08-94

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC) GRADE LEVEL EQUIPMENT CONDUIT RUN PLAN VIEW

SIZE D | DRAWING NUMBER E-170-05 | SHEET 10 | REV 0



NOTES.

1) CONDUIT AND FITTINGS TO BE SUPPLIED BY CONTRACTOR
2) SEE INTERCONNECTION LIST FOR DESIGNATION POINTS
3) ELECTRICAL CONTRACTOR RESPONSIBLE FOR CONDUIT BENDS, JUNCTION BOXES, FLEX CONNECTIONS, RACEWAYS AND HANGERS
4) ALL CONNECTIONS TO MOTORS MUST PASS THRU A DISCONNECT AND FOLLOW ALL NEC REQUIREMENTS
5) WHEN CONDUIT SIZE IS NOT SPECIFIED USE 3/4"
6) UNLESS SPECIFIED USE 16 AWG THHN WIRE

REV	DESCRIPTION	DATE	BY	APPR
1	ADDED SOLENOID VALVE SV-371	12/21/94	RWL	

ITEM	SIZE	REV	REQ	MATERIAL	DESCRIPTION	DRAWING NUMBER	REF NO

SCALE 3/4" = 1'-0"
MATERIAL
FINISH
NO REQUIRED
NEXT ASSEMBLY
ISSUE DATE
SIMILAR TO

TECOGEN
45 FIRST AVENUE WALTHAM MA 02254-9046

UNLESS OTHERWISE SPECIFIED

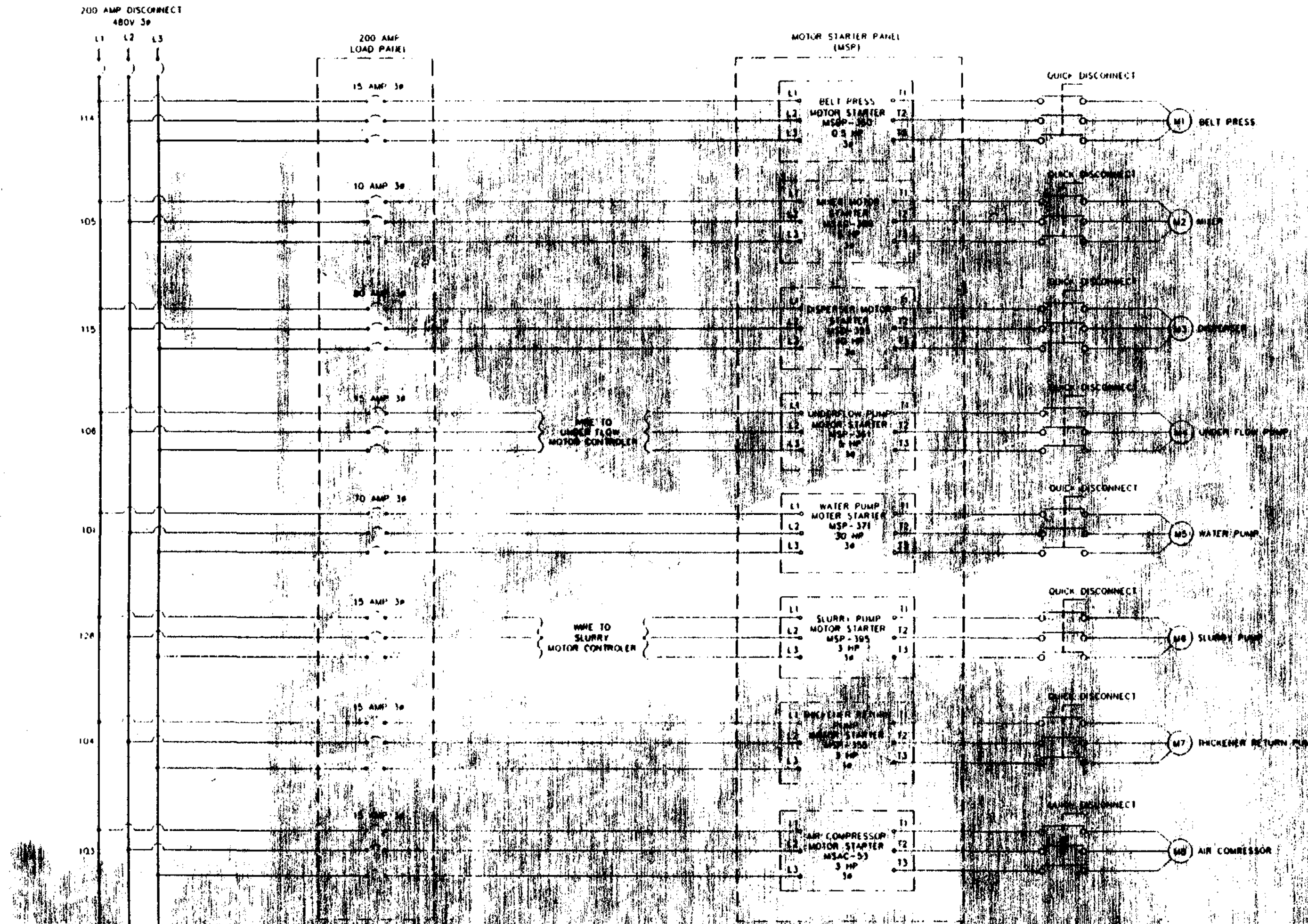
USED ON | DRAWN RWL | DATE 11-09-94 | ENGINEER

TITLE: TWR THICKENER UNDERFLOW CONVERSION (TUC)
THICKENER PUMP RM EQUIP & INST CONDUIT RUN
PLAN VIEW

SIZE	DRAWING NUMBER	SHEET	REV
D	E-170-05	11	1

MSP TERMINAL LIST

101
103
104
105
106
114
115
126
L1
L2
GND



NOTE

1. ALL MOTOR STARTERS LOCATED IN THE MOTOR STARTER PANEL (MSP) UNLESS SPECIFIED
2. SIZE WIRE TO HP RATING
3. 480 VAC WIRING VOLTAGE
4. FOR FACILITY HIGH VOLTAGE WIRING DIAGRAM SEE DWG [illegible]

TECOGEN INC.

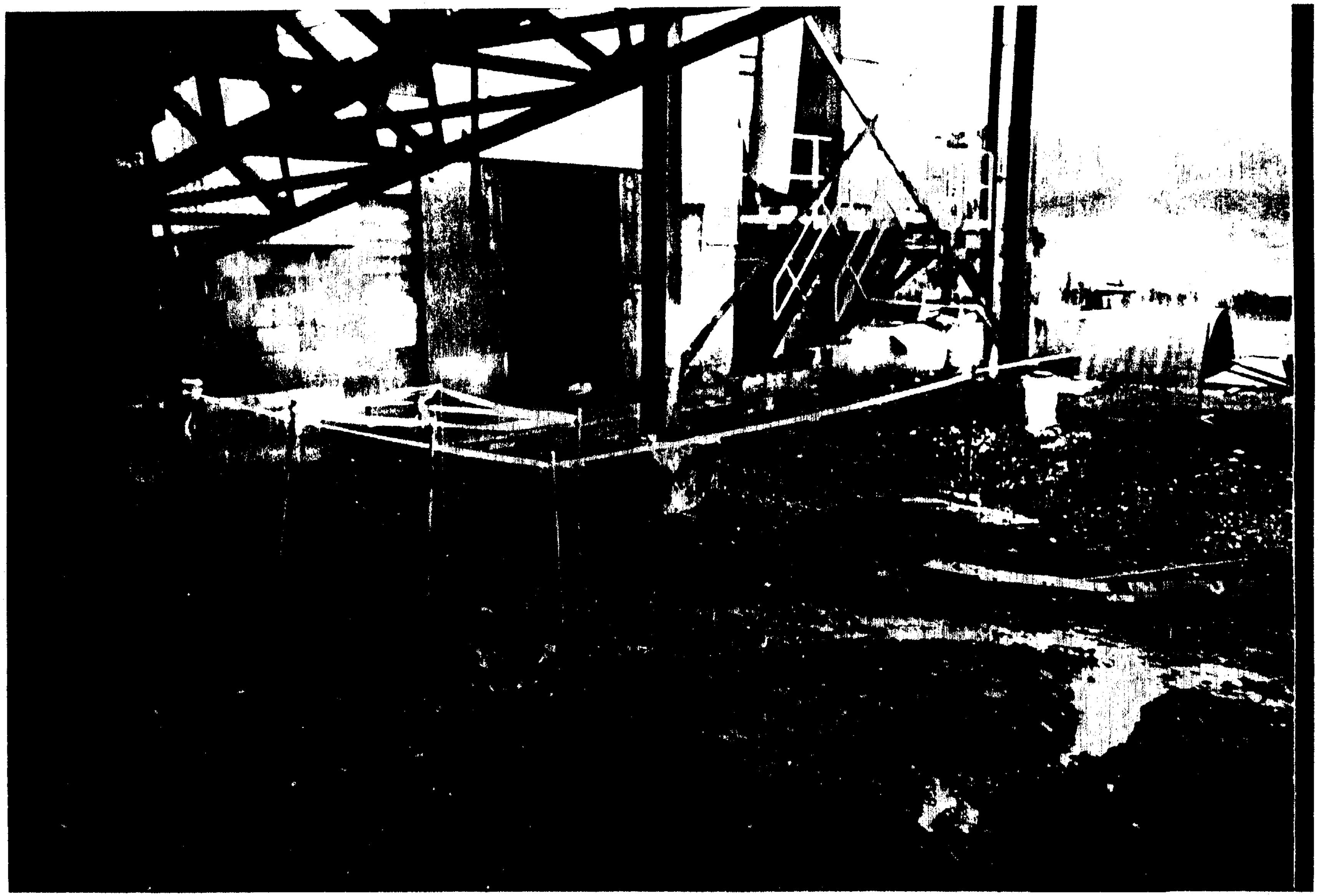
45 First Avenue Waltham, MA 02254-9046

DRAWN	DATE	ENGINEER
DRN-B?	09/08/84	

TITLE LINE-1 JWR THICKENER UNDERFLOW FACILITY HIGH VOLTAGE WIRING DIAGRAM

SIZE	DRAWING NUMBER	SHEET	REV
C	DWG-N-05	NO.	NO

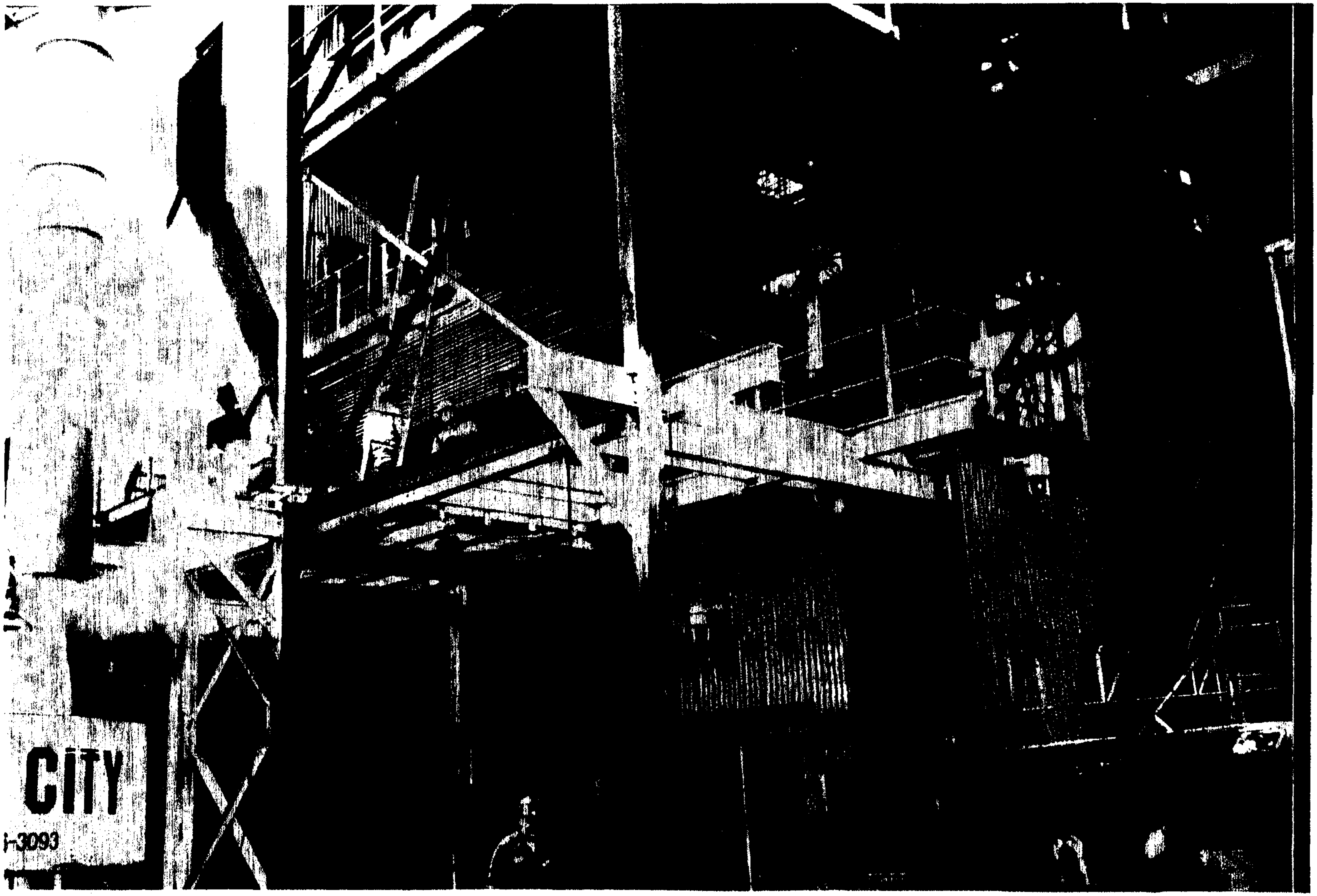
A4 - SITE PHOTOGRAPHS



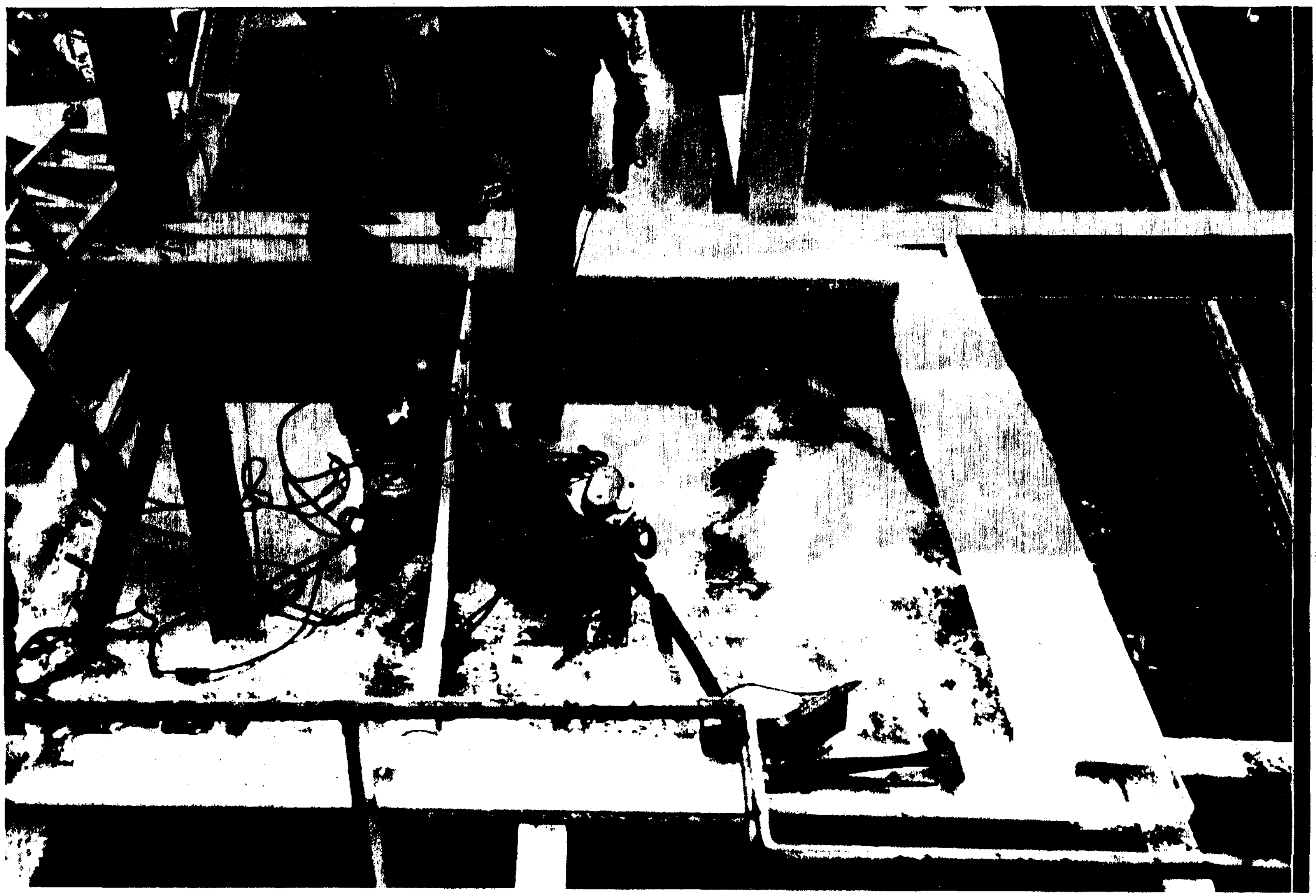
JWR INITIAL BELT PRESS SLAB LOCATION

JWR SITE LOCATION BEFORE BELT PRESS FACILITY INSTALLATION

JWR UNDERGROUND PIPING EXCAVATION

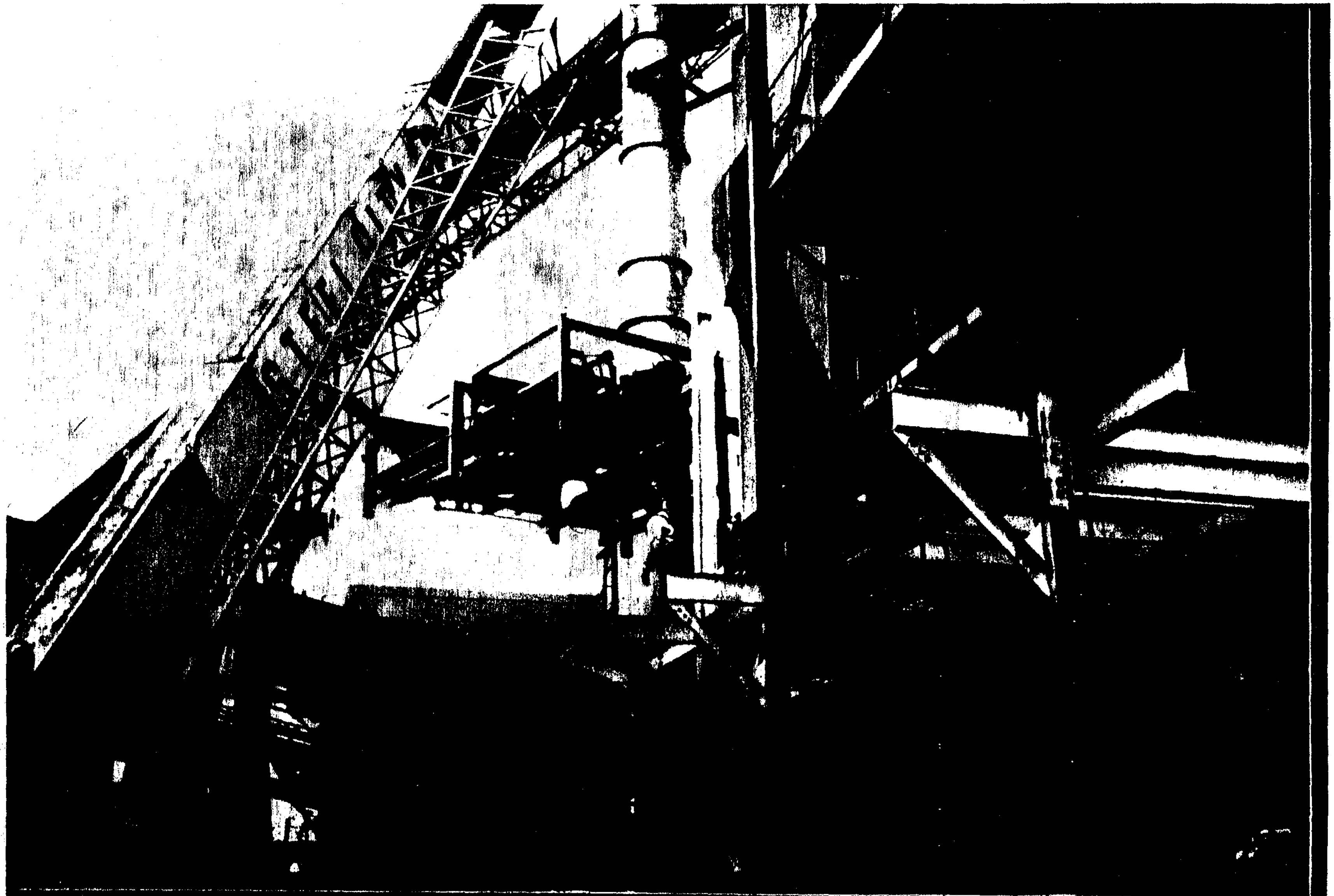


JWR STRUCTURAL STEEL ERECTION

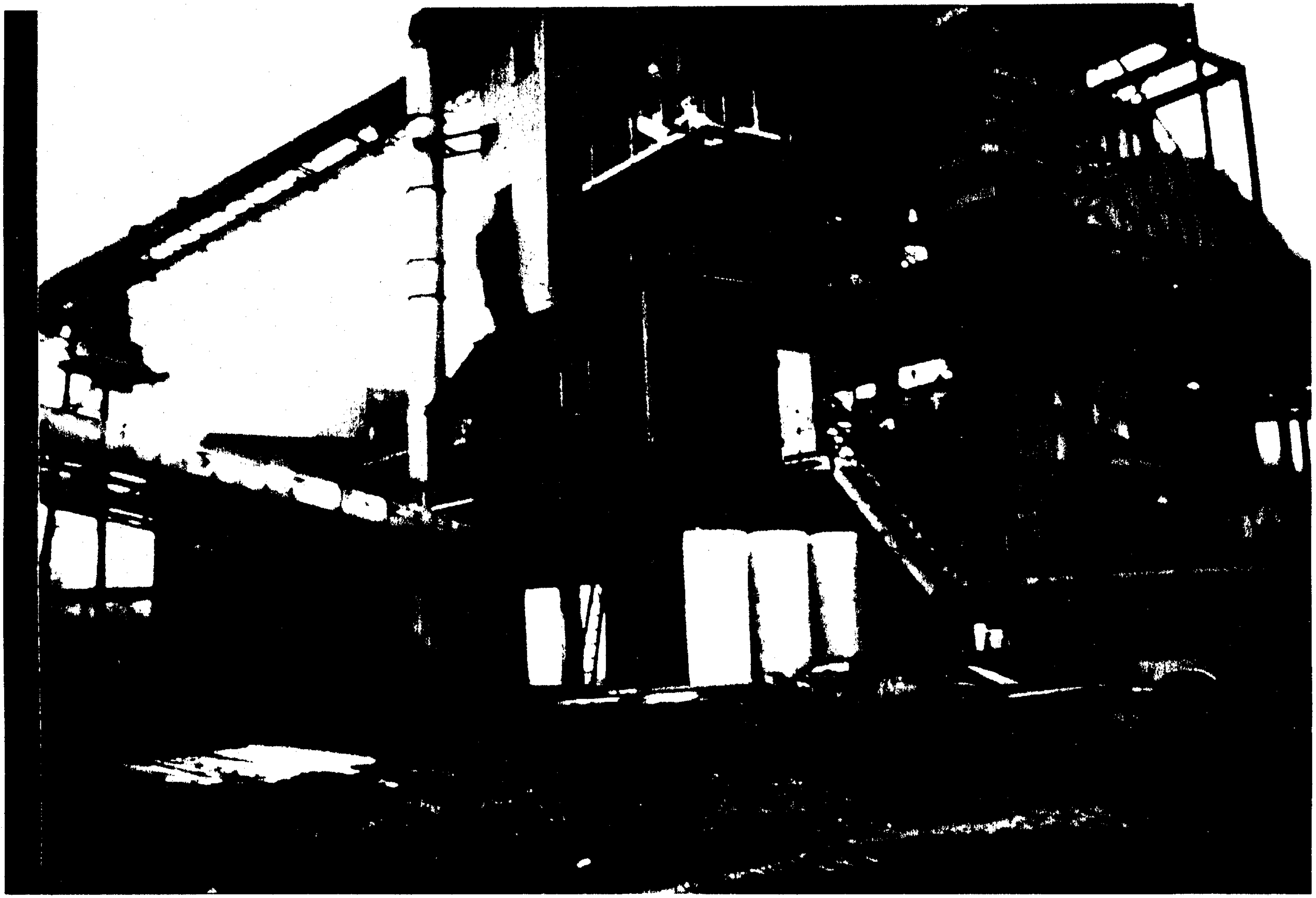


JWR BELT PRESS EFFLUENT WATER COLLECTION PAN WITH BELT PRESS FOOTING LOCATIONS

DELIVERY OF BELT PRESS



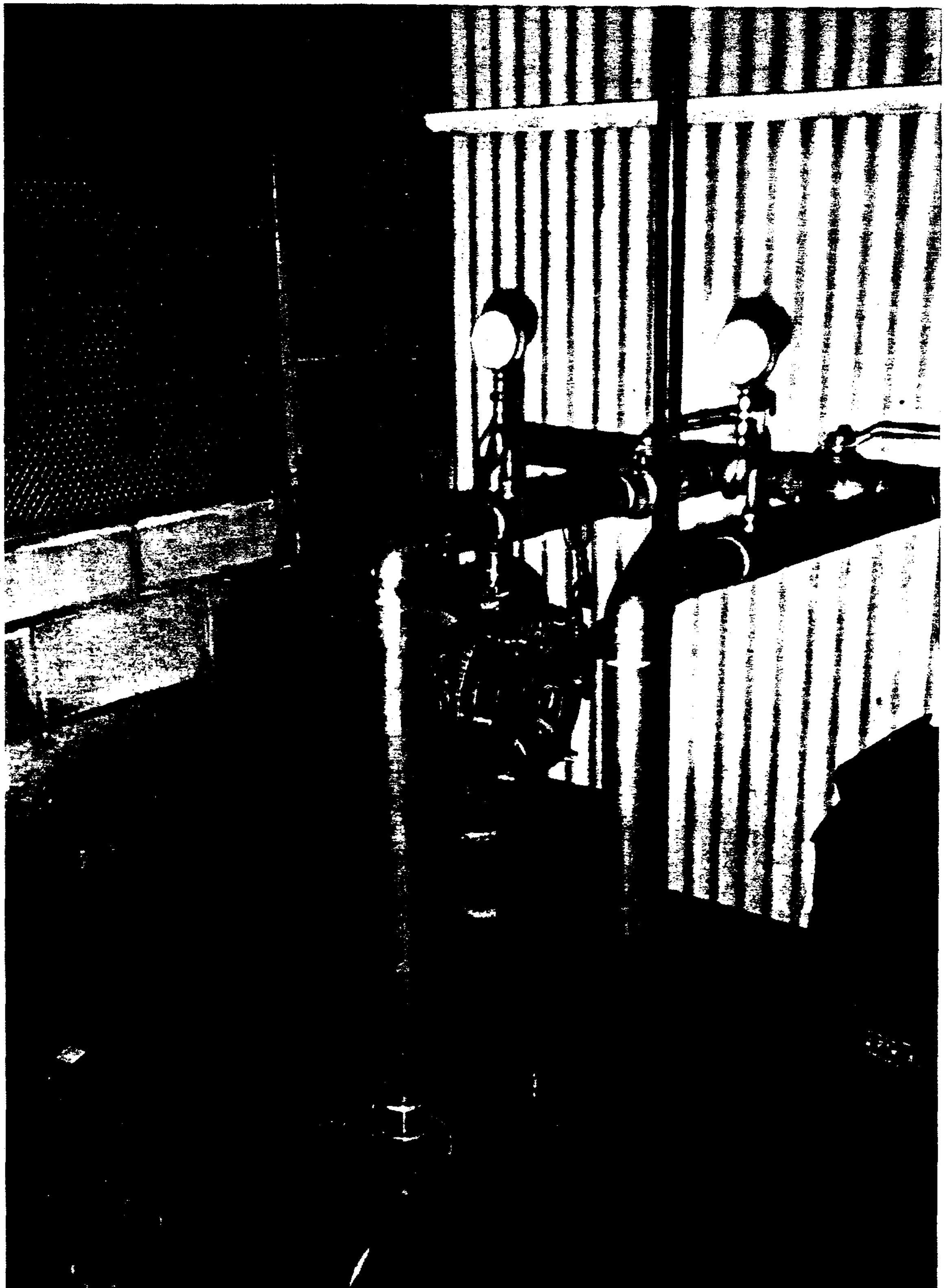
JWR BELT PRESS PLACEMENT



JWR NEW BELT PRESS BUILDING (SIDE)

JWR NEW BELT PRESS BUILDING (FRONT)

JWR FLOCCULENT PIPING LOCATED OUTSIDE
BELT PRESS BUILDING



JWR SUPPLY WATER PUMP AND STRAINER

JWR AIR COMPRESSOR AND DRYER