Dam No. 4 Hydroelectric Plant
4 mi. NNW of Shepherdstown, West Virginia
on the south bank of the Potomac River
Shepherdstown vicinity
Berkeley County
West Virginia

HAER WV-27

PHOTOGRAPHS

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, DC 20240

Addendum to:
Dam No. 4 Hydroelectric Plant
Shepherdstown Vicinity
Berkeley County
West Virginia

HAER No. WV-27

HAER
WVA,
2-SHEP.V
1-

PHOTOGRAPHS

Historic American Engineering Record
National Park Service
U.S. Department of the Interior
Washington, DC 20240

Dam 4 Hydroelectric Plant
Martinsburg vicinity
Berkeley County
West Virginia

HAER No. WV-27

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2-SHEP.V,
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WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

Historic American Engineering Record
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Washington, DC 20013-7127

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HISTORIC AMERICAN ENGINEERING RECORD

Dam 4 Hydroelectric Plant

HAER No. WV-27

Location:	The Dam 4 power plant is located in Berkeley County on the southern shore of the Potomac River, 400 feet west of the confluence of Rockymarsh Run (Berkeley/Jefferson county line) and the Potomac River, in the vicinity of Martinsburg, West Virginia and approx. 4 mi. NNW of Shepherdstown, West Virginia. UTM: 18.256990.4375310 Quad: Shepherdstown
Date of Construction:	The Dam 4 plant was begun in 1906 and placed in operation in 1909.
Present Owners:	Potomac Edison Company (a part of the Allegheny Power System), Downsville Pike, Hagerstown, Maryland 21740
Significance:	Each plant epitomizes the predominant low head hydroelectric technology in use at the time of its construction, Dam 4 uses tandem, multiple-runner, horizontal shaft turbines connected by rope drives to horizontal shaft generators. This plant is probably the last commercially operated rope-driven hydroelectric plant in the United States.
Historian:	Charles Scott, MA, 1982

ACKNOWLEDGMENTS

A number of people have contributed to the preparation of this historical report and it is with gratitude that their efforts are recognized. This project was carried out in cooperation with the West Virginia Department of Culture and History, State Historic Preservation Officer Clarence A. Moran, and the Potomac Edison Company, a part of the Allegheny Power System. Neil Richardson, Engineering Conservator with the Historic Preservation Unit of the Department of Culture and History assisted with the development of the project and field measurement of the Dam 4 plant. Robin Floyd and Steven Six, graduate studets in history at West Virginia University, assisted with the research and initial assembly of the report during the summer of 1980. Two officials of the Potomac Edison Company, Mr. Donald L. Whipp, Supervisor of Publicity, and Mr. Tony Robucci, Superintendent of Minor Stations, generously contributed much time and effort to make available a wide variety of crucial plant records and corporate documents. In addition, Potomac Edison photographer Mr. Dale N. Swope copied the historical photographs which accompany the written report. Mr. Homer T. McCarthy of the Allegheny Power System's Greensburg, Pennsylvania headquarters graciously provided additional plant engineering data.

At the Washington, D.C. office of the Historic American Engineering Record, staff architect Richard K. Anderson Jr. and staff historian William Lebovich provided valuable editorial guidance to assure that the report met Historic American Engineering Record standards. Special thanks is extended to project supervisor John R. Bowie who assisted in the original compilation and initial editing of this document and who also sketched many of the figures appearing in the text.

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ABBREVIATIONS

B&O	Baltimore and Ohio Railroad
C&O	Chesapeake and Ohio Canal Company
EM	Electric Machinery Manufacturing Company
FRC	Federal Records Center, (Philadelphia, Pennsylvania)
H&F	Hagerstown and Frederick Railway Company
MELC	Martinsburg Electric Light Company
MGS	Maryland Geological Survey
MPC	Martinsburg Power Company
MPSC	Maryland Public Service Commission
NA	National Archives, (Washington, D.C.)
NVPC	Northern Virginia Power Company
PEC	Potomac Edison Company
PL&PC	Potomac Light and Power Company
PPSC	Potomac Public Service Company
S&P	Sanderson and Porter, Consulting Engineers
USGS	United States Geological Survey
W&WCRC	Winchester and Washington City Railway Company
WVGS	West Virginia Geological Survey
WVPSC	West Virginia Public Service Commission

INTRODUCTION

A comparison of the designs and the equipment installed in the hydroelectric plants at Potomac River Dam numbers 4 and 5 illustrates the evolution of east coast, low head hydroelectric technology, engineering, and construction during the first two decades of the twentieth century. Until 1894, when the Columbia Cotton Mills in Columbia, South Carolina first used water power to generate electricity, the streams in the industrializing states south of the Mason-Dixon line generated direct mechanical power. [1] Thereafter, while the size and output of eastern and southern hydroelectric plants grew rapidly, many small plants were designed and built to serve isolated industrial customers adjacent to a waterway or a small but rapidly industrializing city within the reach of a 10 to 15 mile transmission line. [2] The first two Potomac River hydroelectric plants fell into this category.

Rapid advances in hydraulic engineering during the early twentieth century brought forth larger, more efficient turbines while, simultaneously, electrical engineers designed larger generating stations linked together by longer transmission lines. The result of these two concurrent developments was the rise of multi-city and, eventually, multi-state and regional electric systems. A comparative analysis of the design and operation of the hydroelectric plants at Dam numbers 4 and 5, built within 25 miles and 10 years of each other, clearly reveals this evolution of hydraulic and electrical technology. The history of the two plants once in operation illustrates the predominant pattern of geographic and financial development of the electric utility industry in the early twentieth century.

While the design and operation as well as the equipment used in these two plants conforms to the prevailing pattern of technical and financial development among electric utilities, hydroelectric development on the Potomac River was unlike that on any other eastern river with a comparably sized drainage basin. When compared to the other east coast streams where low head hydroelectric plants flourished, the Potomac's geography and peculiar flow patterns posed some difficult but not insurmountable problems. Legal and financial rather than engineering barriers determined the pattern of hydroelectric development on the Potomac River. Control of the water of the Potomac by the Chesapeake and Ohio Canal Company seriously reduced the opportunities and incentives for developing the Potomac's potentially large horsepower by restricting the location and number of plants that could be built, shaping and constraining the size and configuration of the plants that were built, and reducing the reliability and output of plants once in operation.

FOOTNOTES: INTRODUCTION

[1] Fraser, J.W. "Electric Power from Southern Waterfalls," Southern Electrician 11 (October 1906): 12.

[2] Ibid.; Switzer, J.A. "Water Power Development in the South," Cassier's Magazine 41 (June 1912): 561-563.

CHAPTER I

WATER POWER AND ECONOMIC DEVELOPMENT ALONG THE POTOMAC RIVER

THE TOPOGRAPHY AND CLIMATE OF THE POTOMAC RIVER VALLEY

The Potomac River originates in the Alleghany Plateau and the Appalachian Mountains in West Virginia, Virginia, Maryland, and southwestern Pennsylvania and forms the boundary between Maryland and West Virginia and Virginia. Two of its primary tributaries, the North Branch, which is the actual headwater stream, and the South Branch unite 15 miles east of Cumberland, Maryland to form the main channel of the Potomac, which flows southeast, cutting through a series of parallel mountain ridges running southwest to northeast. [1] The Potomac receives the water of its largest tributary, the Shenandoah River, at Harpers Ferry, West Virginia, where the two streams cut through Blue Ridge Mountain. [2] Fifteen miles east of Harpers Ferry, at Point of Rocks, Maryland, the Potomac leaves the Appalachian Mountains and follows a meandering southeast path through the rolling hills of the Maryland and Virginia Piedmont Plateau en route to the Coastal Plain. At Georgetown, in the District of Columbia, the Potomac reaches tidewater and empties into a tidal estuary of the Chesapeake Bay. Between the designated headwater city of Cumberland and the District of Columbia, a distance of 108 linear miles, the Potomac River meanders 185 miles. [3]

The Potomac River drains a total area of 14,500 square miles. [4] Almost two-thirds of the drainage basin, a compact 9,230 square mile oval approximately 160 miles long and 80 miles wide, lies west of Harpers Ferry. The path of the Potomac through, rather than between, the ridges of the Appalachian Mountains accounts for the compactness of the drainage basin. [5] No obvious divide or line of high mountains demarcates the outer rim of the drainage basin (see Figure 1).

Flowing southeast, the main channel of the Potomac bisects numerous parallel ridges and valleys that stretch northeast and southwest. Tributaries flow perpendicularly to the main channel, draw water from the narrow valleys between the ridges, and enter the river at 90 degree angles. [6] As they reach further to the northeast and southwest, however, these valleys also feed water to other streams. In Pennsylvania, just 25 miles north of the Potomac's main channel, runoff flows toward the Juniata and Susquehanna Rivers. West of the town of Bloomington and Big Savage Mountain in Maryland, the Big Kanawha and Monongahela Rivers drain the water of the Alleghany Plateau. South of Staunton, Virginia, the headwater of the Shenandoah, the James River also takes runoff from the Shenandoah Valley. The

FIGURE 1

U. S. GEOLOGICAL SURVEY

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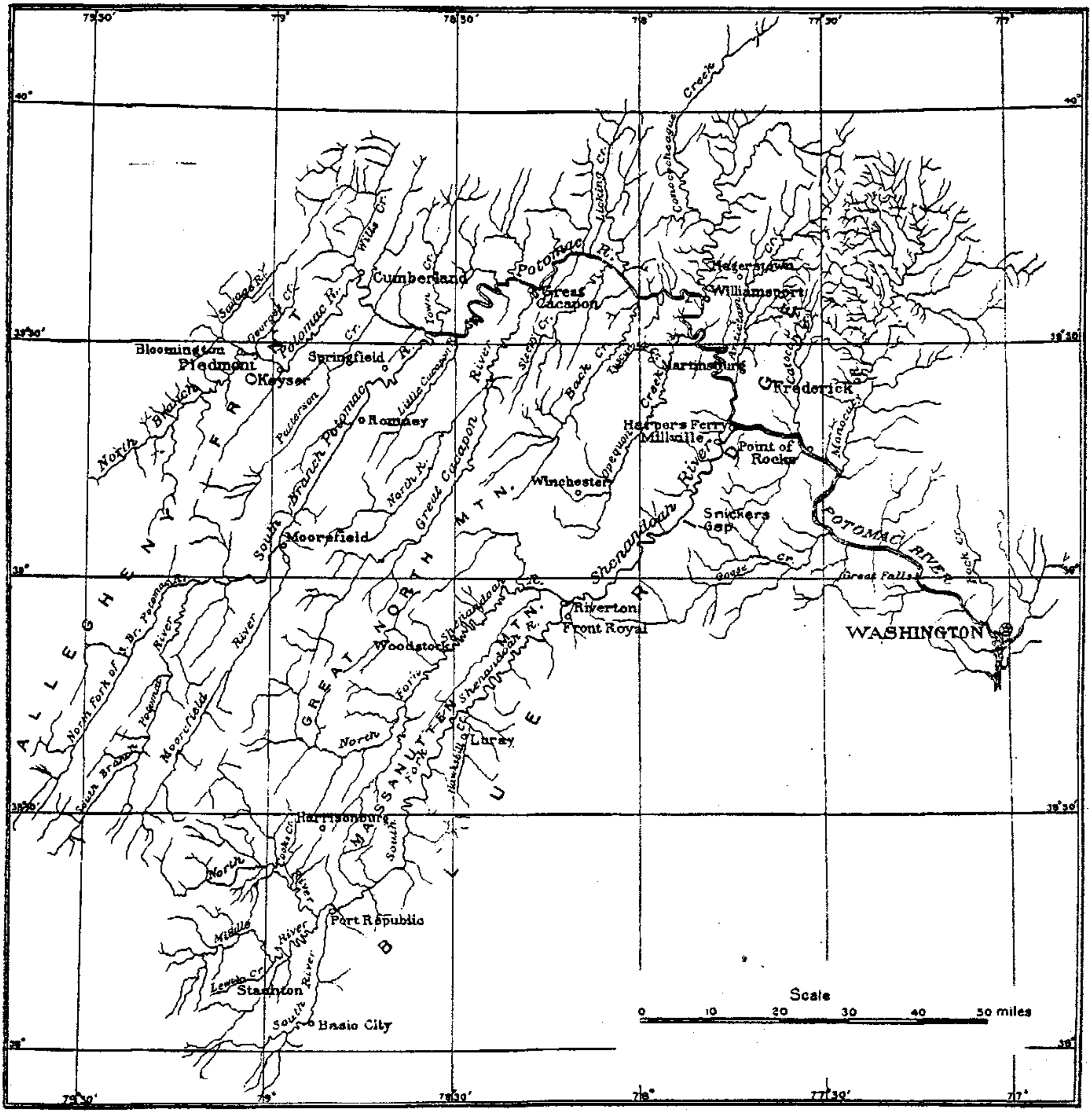

DRAINAGE MAP OF THE POTOMAC BASIN.

Source: USGS, <u>Water Supply Paper 192</u>.

competition for the waters flowing within the Appalachians limits the size and length of the Potomac's tributaries. [7] Short, small tributaries, each draining between 100 and 350 square miles, are all less than 15 miles in length and flow into the Potomac from the North. The southern tributaries, facing less competition, are, on average, slightly longer and larger; the major southern tributary, the Shenandoah River, flows northeast through Virginia and drains almost 3,000 square miles before joining the Potomac at Harpers Ferry. Table 1 lists the significant tributaries and the square mileage each stream drains.

Table 1: [8]

Entering from the north (west to east):

North Branch	1,316 square miles
Town Creek	190
Sideling Creek	121
Licking Creek	185
Conococheague Creek	493
Antietam Creek	343
Catoctin Creek	130
Monocacy Creek	1,010
Seneca Creek	163
Rock Creek	86

Entering from the south (west to east):

South Branch	1,580
Little Cacapon Creek	163
Great Cacapon River	616
Sleepy Creek	214
Back Creek	220
Opequon Creek	286
Shenandoah River	2,850
Goose Creek	466
Occoquan Creek	573

Although the headwater tributaries, the North and South Branches, descend rapidly, as much as 50 feet per mile, the slope of the main channel is gentle. During its 185 mile long course between Cumberland and the District of Columbia, the Potomac descends only 610 feet. Table 2, listing the fall per mile of the North Branch, South Branch, and main channel of the river, clearly illustrates the dramatically different profiles of the Potomac's main channel and its tributaries. Figures 2 and 3 depict the gentle slope interrupted by small falls and rapids which

TABLE 2

SLOPE OF THE POTOMAC RIVER (Main channel and North Branch)

Locality	Distance from tidewater (mi)	Elevation above sea level (ft)	Distance between locality (mi)	Fall between locality (ft)	Fall per mile (ft)
Georgetown, D.C.	0.0	0	----	---	----
Harpers Ferry, West Virginia	61.5	245	61.5	245	4.0
Shepherdstown, West Virginia	71.0	280	9.5	35	3.7
Dam 4	85.0	319	14.0	39	2.8
Dam 5	107.0	357	22.0	38	1.7
Cumberland, Maryland	185.0	600	78.0	243	3.1
(North Branch)	205.0	700	20.0	100	5.0
	211.0	800	16.0	100	16.7
	219.0	1,000	8.0	200	25.0
	225.0	1,200	6.0	200	33.3
	241.0	2,000	16.0	800	50.0
	253.0	2,500	12.0	500	41.7

SLOPE OF THE SOUTH BRANCH OF THE POTOMAC RIVER

Locality	Distance from confluence (mi)	Elevation above sea level (ft)	Fall per mile (ft)
Confluence with North Branch	0	545	----
	15	600	3.7
Romney, West Virginia	27	700	8.3
Moorefield, West Virginia	52	800	4.0
South Fork of South Branch	65	1,000	15.4
	76	1,200	18.2
	87	1,500	27.3
	103	2,000	31.3

Source: USGS, <u>Water Supply Paper 44</u>, pp. 20-21; USGS, <u>Water Supply Paper 192</u>, p. 182.

DAMS 4 & 5
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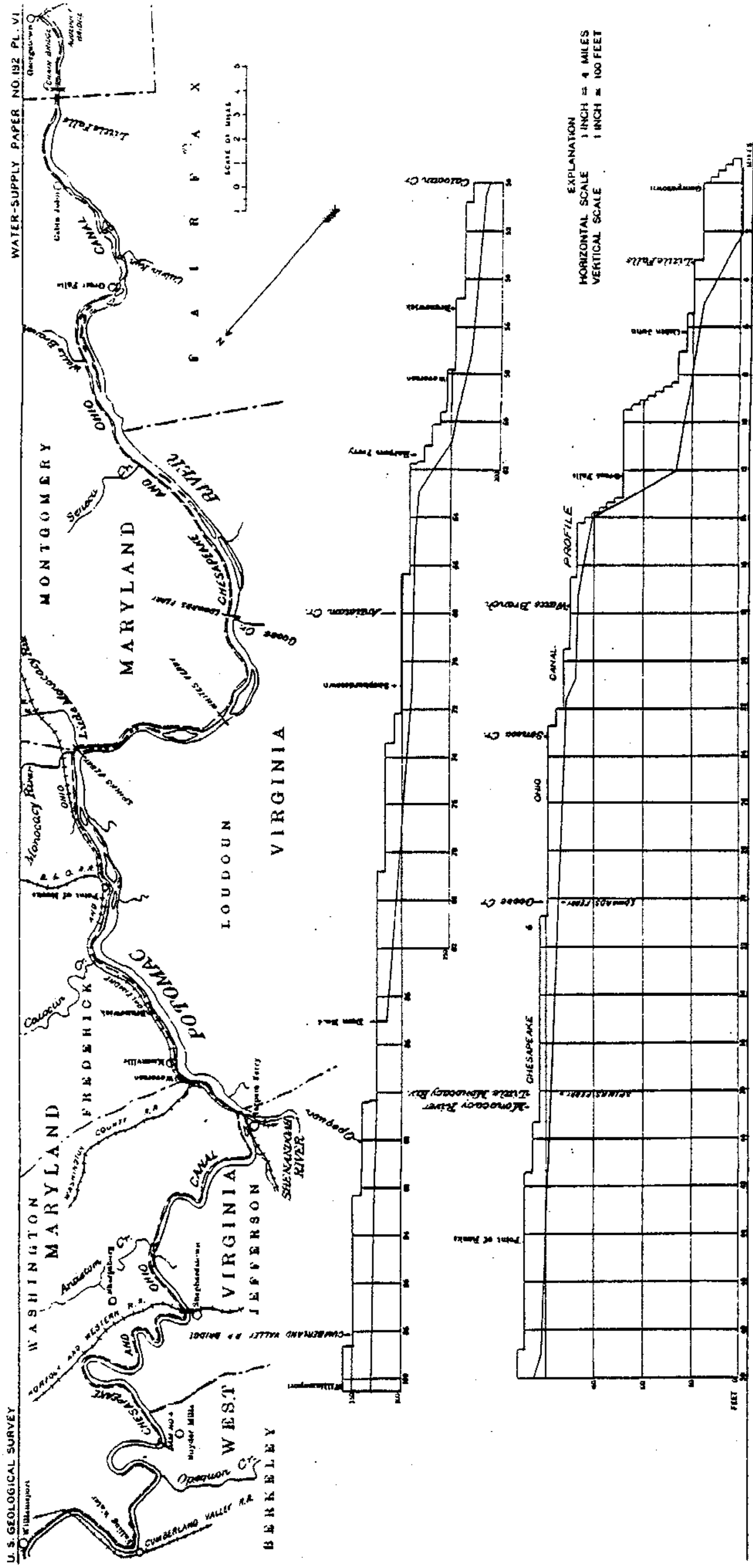
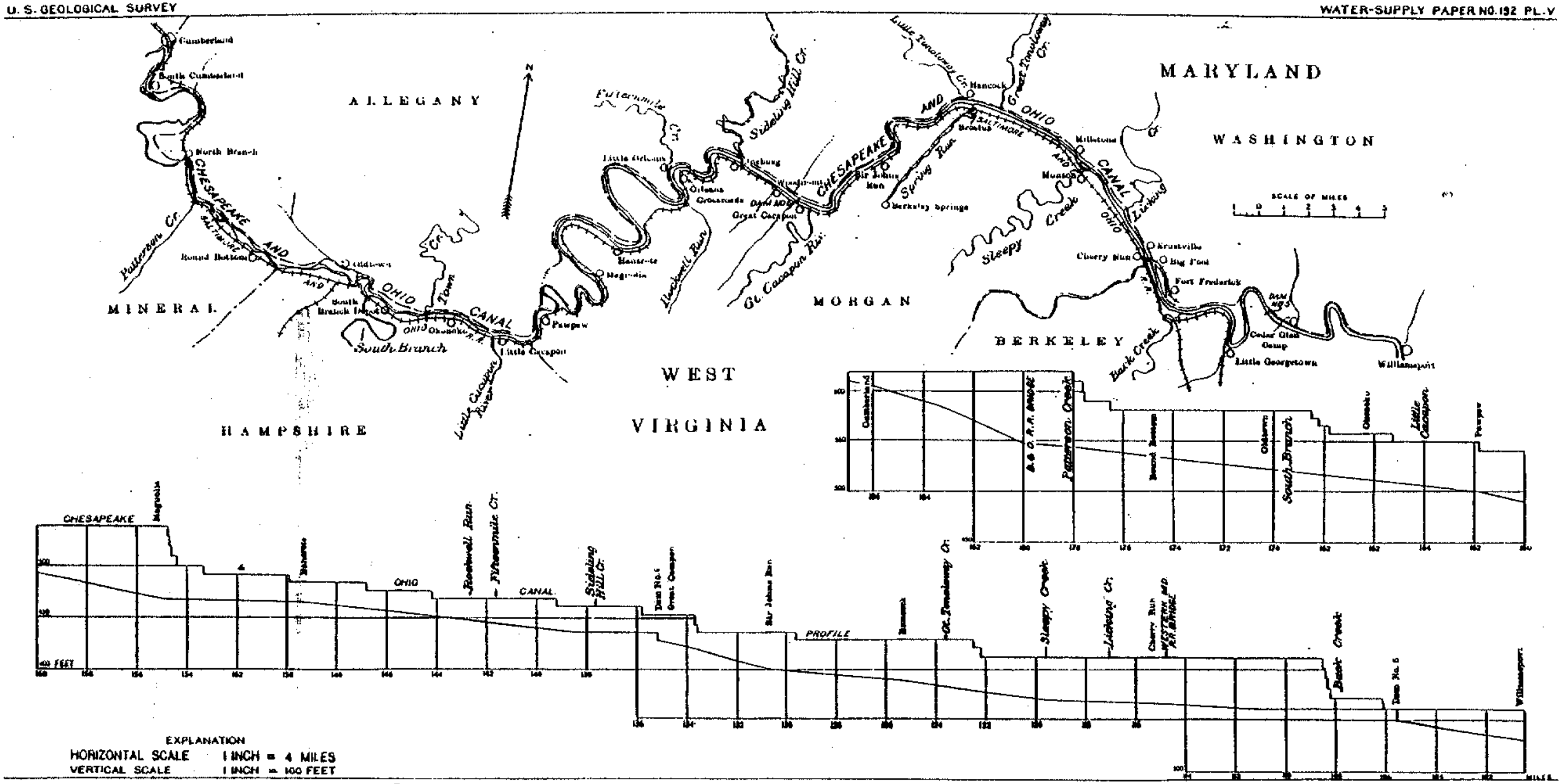


PLAN AND PROFILE OF POTOMAC RIVER FROM GEORGETOWN, D.C.,TO WILLIAMSPORT, MD.



PLAN AND PROFILE OF POTOMAC RIVER FROM WILLIAMSPORT, MD., TO CUMBERLAND, MD.

DAMS 4 & 5
HAER WV-27
(Page 14)

characterizes the main channel. The exception to this pattern is found at Great Falls, west of Georgetown, where the Potomac plunges 90 feet, flows through a series of smaller rapids, and reaches tidewater four miles further downstream. [9]

Precipitation, including rain, snow, sleet, and hail, ranges between 30 and 55 inches and averages 40 inches per year across the drainage basin. Precipitation is heaviest at the western end of the basin and somewhat lighter in the central and eastern sections. Table 3, illustrating the mean monthly precipitation at ten gauging stations within the basin, reveals the irregular distribution and seasonal variations of precipitation. As much as 24 inches, 60 percent of the average total yearly precipitation, falls during the spring and summer months, and only seven to eight inches of the annual total is recorded during the winter. [10] Snowfall averages 36 inches per year; the equivalent of three and one-half inches of rainfall. Snow storage is moderate at the western end of the drainage basin and contributes to a measurable increase in the volume of stream flow during the late winter and early spring months. [11]

THE GEOGRAPHY OF THE POTOMAC RIVER VALLEY

The Potomac River flows through three distinct geographic areas: the Appalachian Region, the Piedmont Plateau, and the Coastal Plain. The character of the river differs in each region and is especially diverse in the Appalachians. This region, forming virtually the entire western half of the drainage basin, consists of four sections: the Alleghany Plateau, the Greater Appalachian Valley, which is subdivided into the Alleghany Ridges and the Great Valley; and the Blue Ridge (see Figure 4). [12]

The Alleghany Plateau, the westernmost section, consists of heavily wooded, broad highlands punctuated by deep, narrow valleys and mountainous ridges rising to elevations exceeding 3,000 feet above sea level. [13] Despite a thick blanket of hardwood forest, steeply sloping hillsides shed precipitation extremely rapidly. Because little water seeps down into the rocky ground, there are few subterranean springs to feed the streams during the dry months. Lakes, ponds, and marshes capable of slowing, capturing, and storing runoff are not found amidst the deep, narrow valleys of the Alleghany Plateau. Short tributaries, all less than 15 miles long, speed runoff through these valleys to the North and South Branches. [14] The steepness of the mountain slopes, the narrowness of the valleys, the shortness of the tributaries, and the absence of natural water storage, features all especially pronounced in the Alleghany Plateau, produce wildly fluctuating stream flow in the headwater tributaries of the Potomac River. [15] During periods of heavy rainfall, the flow of the North and

TABLE 3

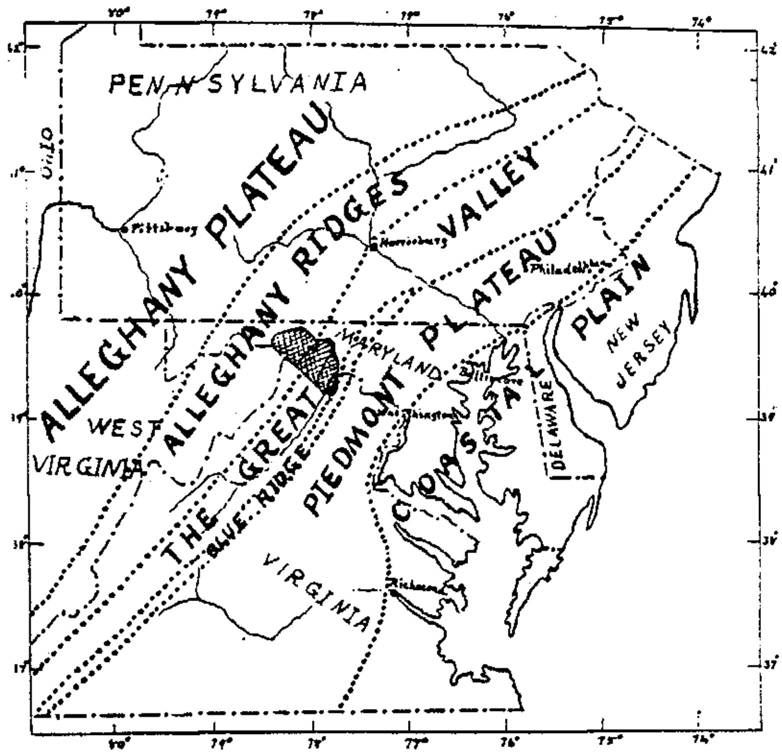
1896-1905 Mean Annual Precipitation in Inches:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Somerset, Pennsylvania, altitude 2,250 ft	4.35	4.38	5.75	4.71	4.17	5.74	5.68	4.72	2.94	2.86	3.28	4.29	52.87
Westernport, Maryland, altitude 1,000 ft	2.31	2.51	3.22	2.74	3.88	4.13	4.40	3.12	2.57	2.13	2.07	2.29	35.41
Cumberland, Maryland, altitude 700 ft	2.60	2.72	3.52	2.77	3.26	3.27	3.12	3.20	2.35	2.36	2.38	2.85	34.55
Staunton, Virginia, altitude 1,380 ft	2.62	3.13	3.54	2.95	4.19	4.52	3.97	3.69	3.16	2.78	2.10	2.71	39.43
Hancock, Maryland, altitude 455 ft	2.76	1.83	3.17	3.79	2.67	5.27	4.71	3.81	2.16	2.45	1.48	3.41	37.54
Hagerstown, Maryland, altitude 550 ft	2.27	4.28	4.13	1.31	3.02	3.54	3.73	3.85	2.56	2.37	3.25	2.21	36.52
Martinsburg, West Virginia, altitude 435 ft	2.32	2.15	3.29	2.73	3.74	4.40	4.72	3.48	2.66	2.30	2.62	2.53	37.65
Harpers Ferry, West Virginia, altitude 277 ft	2.91	3.06	3.93	2.70	4.02	3.81	4.44	3.50	2.95	2.83	2.73	3.32	40.25
Point of Rocks, Maryland, altitude 235 ft	2.53	2.90	3.41	2.61	3.77	4.14	4.15	3.49	2.64	2.36	2.21	2.71	36.99
Washington, D.C., altitude 112 ft	3.08	3.97	3.68	2.82	3.41	4.16	4.87	4.40	3.16	2.85	2.27	3.48	42.20
Monthly Averages	2.78	3.09	3.76	2.91	3.61	4.30	4.38	3.72	2.72	2.54	2.44	2.98	39.34

Source: USGS, Water Supply Paper 92, pp. 34-40.

FIGURE 4

POTOMAC RIVER VALLEY TOPOGRAPHIC REGIONS



Source: WVGS, County Reports: Jefferson, Berkeley, Morgan Counties, p. 36.

South Branches is "swift and precipitous." [16] Swells, floods, and freshets are sudden, heavy, and frequent. [17]

Unlike the tributaries of the Shenandoah River, fed year round by an abundance of subterranean springs, many tributaries of the North and South Branches flow intermittently, primarily during wet weather. Without springs to feed them, the streams of the Alleghany Plateau become mere rivulets during the dry months, and, consequently, the total annual flow into the North and South Branches is exceedingly small. [18] The range between the extreme high and low flow reveals the magnitude of the wild variations of flow. In 1897, not a record flood year, the peak flow on the North Branch at Cumberland, 20,735 cubic feet per second (cfs), was 2,073 times greater than the low flow of 10 cfs. [19] Table 4 illustrates the extreme variations in the flow of the North Branch during a single year. These fluctuations and exceedingly low flows, both greater here than on any other eastern stream with a comparably sized drainage basin, were the primary impediments to the extensive development of water power on the headwaters of the Potomac River. [20]

At the confluence of the North and South Branches, the lush forest of the Alleghany Plateau yields to the more diverse topography of the Greater Appalachian Valley. This region, a mixture of narrow, limestone laden valleys and extensively cultivated, rolling hills, is subdivided into two sections: the Alleghany Ridges on the west and the Great Valley (also known in Maryland as the Hagerstown Valley, in Pennsylvania as the Cumberland Valley, and in Virginia as the Shenandoah Valley) on the east. [21] Numerous parallel ridges and steep, narrow valleys dominate the topography of the Alleghany Ridges. Moving east, the ridges slowly begin to diminish in height and increase in width, and the the deep, narrow valleys, especially those south of the Potomac's main channel, begin to lengthen to accomodate longer tributary streams. The Great Valley, lying between the Alleghany Ridges on the west and the Blue Ridge on the east, is a broad lowland characterized by rolling hills and rich limestone fortified soil which sustains an extensive band of agriculture in both West Virginia and Maryland. [22]

Despite dissimilar topography, both the Great Valley and the Alleghany Ridges share a common inability to retain runoff. In both of the Greater Appalachian Valley's two sections, as in the Alleghany Ridges, the natural bodies of water are insufficient to adequately retard runoff and store precipitation. In the narrow valleys of the Alleghany Ridges, rainfall cascades down steep, lightly forested, rocky slopes and transforms normally gentle streams into roaring, silt laden torrents. In the Great Valley, it is the extensive cultivation of the rolling hills which allows the runoff to flow rapidly and relatively unimpeded into the Potomac and its tributaries. Both the volume and the swiftness of

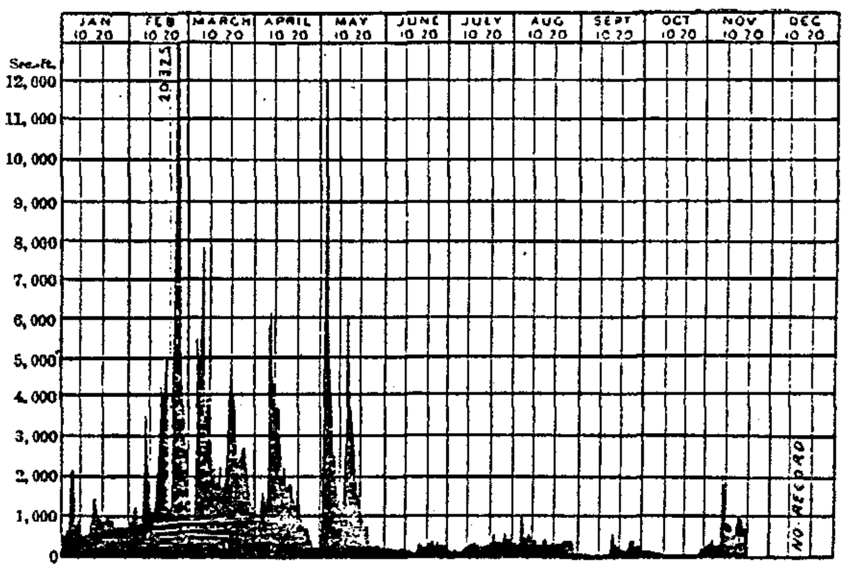
TABLE 4

POTOMAC RIVER STREAM FLOW DATA, CUMBERLAND, MD.

[Drainage area, 891 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	2,175	525	836	51,404	1.08	0.94
February	20,375	835	3,610	200,489	4.21	4.05
March	7,775	1,165	2,744	168,720	3.55	3.06
April	6,095	180	1,570	93,421	1.96	1.76
May	11,975	180	2,162	132,936	2.79	2.42
June	255	80	165	9,818	0.21	0.19
July	525	85	199	12,236	0.25	0.22
August	990	85	256	15,741	0.33	0.29
September (a)	525	10	70	4,165	0.09	0.08
October (a)	110	20	40	2,460	0.04	0.04

a Approximate.



Source: USGS, Nineteenth Annual Report: 1897-1898, p. 147.

the runoff originating in the Greater Appalachian Valley intensifies the existing variations of the Potomac's flow, and floods and freshets are as common here as further upstream. [23]

The Blue Ridge is the eastern most third of the Appalachian region. The mouth of the Shenandoah River, the Potomac's largest tributary, is at Harpers Ferry, at the western edge of the Blue Ridge. Despite the effects of the more uniform flow of the Shenandoah, the flow of the Potomac through the Blue Ridge is still highly variable and freshets, rising as much as twenty-five feet, have been recorded. [24]

At Point of Rocks, Maryland, the Potomac leaves the Appalachian Region and begins its passage through the gently rolling hills of the Piedmont Plateau toward the Coastal Plain. Piedmont tributaries of the Potomac River are significantly longer and larger than the typical Appalachian Region tributaries and, consequently, between Point of Rocks and tidewater the extremes between high and low flow are less severe and the average flow is more uniform. [25]

WESTWARD EXPANSION AND THE POTOMACK COMPANY

A highly variable flow has been the significant, but not the exclusive characteristic shaping the use of the Potomac River and posed the primary, but not the sole impediment to using its waters as a source of power. During the late 1700s, the rugged ridges of the Appalachian and Alleghany Mountains stood as a formidable obstacle to westward migration and commercial expansion, and focused attention on the potential of the Potomac River as a natural highway to the West. [26] As early as 1750, commercial interests and advocates of westward expansion envisioned using the river as a commercial highway linking the eastern seaboard with the Ohio River Valley and Great Lakes regions. As a first step toward fulfilling this grand dream, the Potomac Company, chartered in 1785, sought to render the Potomac River navigable by deepening the channel, removing small rapids, and building canals around the large falls, such as Great Falls. The Potomack Company, despite the construction of canals around some of the larger rapids, failed to significantly improve the navigability of the Potomac River. [27]

Proponents of internal improvements renewed the agitation to develop the Potomac as a commercial highway during the 1820s. Guided by the success of New York State's Erie Canal, entrepreneurs and politicans focused their attention on creating a permanent, artificial means of navigating between the District of Columbia and Pittsburgh, at the head of the Ohio River. In 1824, the United States Board of Engineers surveyed the Potomac and the states of Maryland and Virginia incorporated the Chesapeake and Ohio Canal Company to undertake the actual construction of the proposed canal. [28] The following year, the Board of Engineers issued reports endorsing the technical feasibility of a canal along the banks of the Potomac and the United States Congress approved the project, however, actual construction did not begin until 1828 when the property and water rights of the defunct Potomac Company were finally legally transferred to the Chesapeake and Ohio Canal Company. [29]

CONSTRUCTION OF THE CHESAPEAKE AND OHIO CANAL

Engineers divided the first half of the canal, the 185 mile long section between Georgetown and Cumberland into eight levels. At the upstream (western) end of each level a dam was built across the Potomac to impound and divert water into the canal. [30] Chief Engineer Thomas Purcell, after conducting a survey of potential dam sites, recommended the construction of two of the eight dams, numbers 4 and 5, adjacent to the Virginia (West Virginia after 1863) counties of Jefferson and Berkeley. Accepting the designs submitted by Purcell, the Chesapeake and Ohio Canal Company built the two dams using rubble and gravel filled timber cribs anchored into the rock streambed by one and one-half inch wide iron rods driven into the streambed at ten foot intervals. Like the south end of Dam 4, the dams were anchored into solid rock riverbank whenever possible. When the riverbank adjacent to the dam was not solid rock, a rubble masonry abutment laid in hydraulic cement provided the necessary lateral support. Dams 4 and 5, both begun around 1832, were completed in 1835. [31]

Dam number 4 was located five miles upstream from Shepherdstown, West Virginia and Dam number 5 was built seven miles upstream from Williamsport, Maryland. Both dams leaked heavily, failed to supply the canal with an adequate volume of water, and proved incapable of withstanding the often violent flow of the Potomac. In 1853, 1854, and 1856, the inability of the two dams to impound and divert a sufficient amount of water halted canal operations for periods as long as two months. [32] The frequent disruption of canal traffic because of an inadequate water level forced the Chesapeake and Ohio Canal Company to build more substantial, impervious, and expensive masonry structures immediately downstream from the original timber crib dams. [33] The wisdom of this course of action was demonstrated in February 1857, before construction of the new dams had begun, when an ice freshet heavily damaged Dam 4 and swept away 500 feet of Dam 5. Three other floods during that same year hindered repairs, further damaged the existing timber crib structures, and delayed construction of the new masonry dams. [34] Floods, insufficient funds, and the Civil War further delayed the completion of the two masonry dams until 1869. [35] The new Dam 4 measured 715 feet between abutments and reached a maximum height of 20 feet. Dam 5 was 711 feet long between abutments and rose 22 feet above the streambed. Each dam had a vertical, cut stone face and a rubble core 20 feet deep at its base and tapered inward to create a six foot wide, angular crest covered by three inch thick plank ice guards (see Figure 5). [36] The new masonry dams proved impervious to water, but failed to withstand the more violent surges of the Potomac. In 1877, the worst flood up to that time swept away 200 feet of Dam 4 and shattered the dam's reputation as "one of the best of its kind in the country." [37] The raging waters also seriously undermined the abutments of Dam 5. Both dams suffered again in 1889 when another flood, exceeding the severity of the 1877 flood, left the canal a "total wreck." [38]

These floods demonstrated how the Potomac's unpredictable rage constantly disrupted canal traffic and frequently damaged the canal. As the lush woodland along the Potomac River was deforested and cleared for cultivation and development, runoff increased and became swifter, producing increasingly ferocious and more destructive floods. [39] The West Virginia Geological Survey reported that, despite a 40 percent increase in the periods of low flow, the number of floods increased 36 percent and the total volume of water annually discharged by the Potomac River increased eight percent between 1892 and 1910. [40] Those statistics led the West Virginia Conservation Commission to conclude:

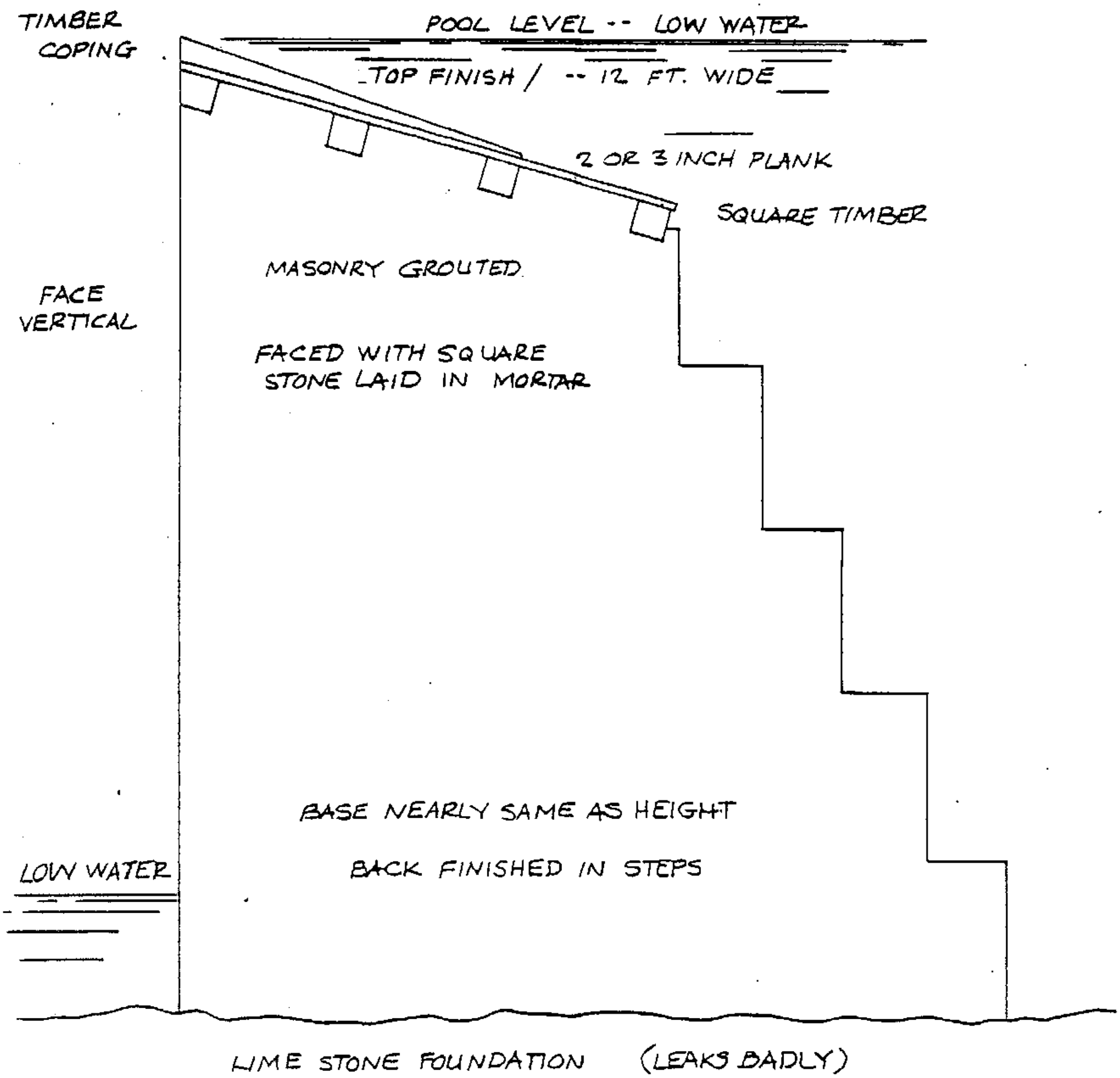
> The increase of the total discharge, in spite of diminishing rainfall and a greater fluctuation than formerly in the periods of high and low water, is due solely, so far as available data can be interpreted, to the deforestation of the mountains. There is no reason to doubt that a continuation of the timber cutting and burning will increase the fluctuation of the streams... [41]

While the floods were unpredictable, they struck with "depressing regularity." [42] Twenty-four extremely destructive floods inflicted damage upon the canal during its 104 years of operation, and not a single year passed without some form of interference to the canal from natural elements. [43] In addition to floods, ice flows often damaged the dams and disrupted canal traffic. Spring thaws brought sheets of ice that periodically slashed gaping holes in both the dams and the canal banks. Less destructive, but equally disruptive to canal navigation were droughts and periods of low water which reduced the volume of water available for diversion into the canal and halted traffic for as long as eight weeks. [44]

The floods, freshets, ice, and droughts wrought havoc not only upon the operations, but also the finances of the Canal Company.

FIGURE 5

SECTION, CHESAPEAKE AND OHIO CANAL DAM 4



BASED ON:
CHESAPEAKE AND OHIO CANAL CO.
SECTIONS OF DAMS # 4 & 5. AS PER LETTER OF
W. R. HUTTON AUG. 3, 1900

DAM #4, 810 FT. LONG, 20 FT. HIGH
DAM #5, 706 FT. LONG, 21 OR 22 FT. HIGH

Interruptions of canal traffic substantially reduced the Canal Company's income and repairing the damage inflicted upon the canal by the Potomac's often violent flow required the annual expenditure of large sums of money. [45] The dismal experience of the Chesapeake and Ohio Canal Company's battle against the tempermental Potomac River was a disheartening lesson to those contemplating the river as a source of reliable and inexpensive power for large scale industry.

The highly variable flow impeded and discouraged, but did not totally preclude the use of the Potomac as a source of power. On the North and South Branches, the extremes between high and low flow as well as the frequency and the severity of the floods and freshets demanded the use of far more elaborate and expensive dams than the commonly used rock filled, timber crib mill pond dams. Because of the expense and difficulty of building dams on the headwaters of the Potomac, the cost of harnessing the steeply falling, erratically flowing water of these streams was prohibitive. [46] Below Cumberland, on the main channel of the Potomac, a larger minimum flow and a more gently sloping streambed (see Table 2 and Figures 2 and 3) offered more hospitable conditions for the development of water power. A United States Geological Survey report acknowledged the Potomac's highly variable flow and the absence of facilities to store water, but concluded:

> In all other respects the conditions are favorable to the development of water power. In several places large falls might be rendered available. Good rock foundations can be found near the surface, and the banks are high and rocky, and suitable for the construction of high dams. The local rock, which abounds, makes an excellent building material for dams; and this rock and other materials could be easily transported on the Chesapeake and Ohio Canal, which follows close to the river, on the Maryland side, from Washington to Cumberland. [47]

In 1880, engineers of the United States Census of Manufactures calculated that a minimum of 17,485 and a maximum of 170,620 horsepower was available using existing dams and two undeveloped water falls. Table 5 lists the potential and developed water power in 1880. Thirty years later, the National Conservation Commission estimated that between Cumberland and Harpers Ferry, a distance of 126 miles, the flow and fall of the Potomac could generate a maximum of 58,930 and a minimum of 14,344 horsepower. [48]

The 170,620 horsepower potential of the Potomac River, however, was never realized. The Potomac channeled trade and commerce

TABLE 5

WATER POWER DEVELOPED ON THE POTOMAC RIVER

Summary of estimates of flow and power of the Potomac river.

Name of place.	Distance from Georgetown.	Drainage area.	Rainfall. Spring.	Rainfall. Summer.	Rainfall. Autumn.	Rainfall. Winter.	Rainfall. Year.	Total fall. Length.	Total fall. Height.	Horse-power available, gross.(a) Minimum.	Horse-power available, gross.(a) Minimum low season.	Horse-power available, gross.(a) Maximum with storage.	Horse-power available, gross.(a) Low season, dry years.	Utilized. Fall.	Utilized. Horse-power, net.	Remarks.
	Miles.	*Sq. miles.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Miles.*	*Feet.*					*Ft.*		
Dam No. 1 (Little falls)	5	11,556	11	12	9	8	40	......	10+	1,220	2,248	11,700	2,600	...	....	Dam 7 feet high. Power utilized below, at Georgetown.
Great falls	14	11,476	11	12	9	8	40	1½	80–90	9,720	17,730	92,840	20,000	...	....	
Dam No. 2	....	11,259	11	12	9	8	40	......	Small.	....	....	....	....	...	....	
Weverton	57	9,260	11	12	9	8	40	3	25	2,440	4,460	23,400	5,100	...	....	
Harper's Ferry	60	6,380	11	12	9	8	40	1½	22±	1,430	2,550	14,350	2,900	...	....	
Shepherdstown	70±	5,975	11	12	9	8	40	......	8	480	800	4,880	920	8	20–30	Dam 8 feet high.
Dam No. 4	85	5,899	11	12	9	8	40	......	15½	775	1,500	9,300	1,725	...	....	Dam 15½ feet high.
Dam No. 5	106	5,065	11	12	9	8	40	......	16½	700	1,420	8,550	1,625	...	....	Dam 16½ feet high.
Dam No. 6	136±	3,550	11	12	9	8	40	......	15½	440	875	5,000	1,000	...	....	Dam 15½ feet high.

WATER POWER DEVELOPED ON THE C&O CANAL

Name of place.	Kind of mill.	Number of square inches.	Head.	Quantity of water per second.	Head and fall.	Horse-power, gross.	Remarks.
			Feet.	*Cubic feet.*	*Feet.*		
Georgetown	Paper	417	a4	....	34.5	....	Head and fall of 34.5 feet to mean high tide; discharge to river.
Do.	Corn	328	a4	....	34.5	....	
Do.	Fertilizers	229	a4	....	34.5	....	
Do.	Flour	2,595	a4	....	34.5	....	
Do.	Not used	731	a4	....	34.5	....	
Total in Georgetown	....	4,300	a4	310±	34.5	1,214±	
Berlin, Frederick county	Flour and fertilizers	....	....	(Estimated) 55	6	37	Flume-water of one lock.
Weverton	Flour	....	....	....	17	25–30	Waste water leased; discharged to river.
Above Antietam aqueduct	Saw	50	....	Small	8–10	....	Discharged to river.
Williamsport lock	Saw	....	....	....	8	....	Flume-water.
Williamsport aqueduct	....	....	....	....	28	....	Discharged to river.
Above dam No. 5	....	33	2	Small	....	....	Discharged to river.
Hancock	Grist	200	4	....	24±	....	
Above Hancock	Cement	500±	3–4	....	24±	....	

a Or less.

Source: U.S. Bureau of the Census, Tenth Census, Reports on the Water Power of the United States, pp. 560, 563.

between Chesapeake Bay and the region west of Cumberland, but, unlike streams in the New England and South Atlantic states, did not sustain water powered industry. The Chesapeake and Ohio Canal Company's control of the Potomac River water rights and the primary obligation of the Canal Company to use the river water to maintain a constant, navigable water level, selling only surplus water when available, retarded the development of water powered industry along the Potomac River even more than the fluctuating flow.

RIPARIAN RIGHTS AND THE CHESAPEAKE AND OHIO CANAL COMPANY

Although Maryland owned the land as far as the low water line on the south shore, common law and legislation enacted in 1785 permitted both Maryland and Virginia (and after 1863, West Virginia) landowners along the Potomac River to use the water adjacent to their property. [49] The 1785 charter of the Potomack Company specified:

> ...the water or any part thereof conveyed through any canal or cut made by said company shall not be used for any purpose but navigation unless the consent of the proprietors of the land through which the same flows shall first be had. [50]

When the Potomack Company failed and the Chesapeake and Ohio Canal Company assumed the construction of the waterway, the new company also assumed the legal rights of its corporate predecessor. [51] The original charter, however, did not grant the Chesapeake and Ohio Canal Company the right to sell "surplus" water not drawn into the canal and left to flow over the company's dams; it permitted the Canal Company to draw only the water needed to maintain canal navigation and sell only "waste water" discharged to maintain the waterway's structural "security." [52] To remove this restriction, the Canal Company petitioned for complete riparian (water) rights to the Potomac River. Virginia, not owning the waterway, readily consented and approved the request in February 1829. [53] Maryland property owners, reluctant to forfeit their traditional riparian rights, did not consent to the Canal Company's request until 1833. [54] The act ratified by the Virginia legislature permitted the Canal Company to "sell, let, or otherwise dispose of any surplus waters in any part of said canal or any feeders or reservoirs thereof," as long as such sales did not adversely effect canal navigation or violate the riparian rights of others. When the Maryland legislature consented to the Canal Company's request, it added a provision, not repealed until the 1890s, prohibiting the use of water obtained from the Canal Company for the milling of grain within the State of Maryland. [55] With the approval of the United States Congress in

1837, the Chesapeake and Ohio Canal Company possessed complete control over the use and distribution of all the water flowing in the Potomac River.

The Canal Company leased water flowing in both the canal and the Potomac River for water power generation. The sale of water brought additional revenues and additional traffic from the water powered industries located along the canal. [56] Wide variations in the volume of Potomac River water available for diversion into the canal and the widely varying, uncertain, and irregular needs of the canal, affected by weather, traffic volume, evaporation, and leakage, prohibited reliable calculations of the volume of water available for powering industrial operations. Water power users were guaranteed neither a specific head nor quantity of water. Businesses using water obtained from the Canal Company found the necessity of regulating their operations in accordance with canal navigation a highly undesirable restraint on continuous production. Water obtained from the canal was highly intermittent during the eight months of the year when the canal operated and totally unavailable during the four winter months when the canal was drained to prevent damage from the formation of ice. [57] Mills and factories powered by water drawn directly from the Potomac River were assured of water without interruption or restrictions only during the three Winter months when the canal was not operating.

In 1835, the Canal Company leased water rights at various points downstream from Harpers Ferry only to discover very shortly thereafter that there was insufficient water for both navigation and water power projects. [58] Some years later, after completion of the canal as far west as Cumberland, the Canal Company concluded that because of the often inadequate volume of water, the outlook for expanding water power usage was "not promising." [59] In 1880, for example, water supplied by the canal generated a maximum of 1,281 horsepower, of which approximately 1,214 horsepower was generated in the vicinity of Georgetown where the proximity of markets and the availability of labor and capital encouraged water powered manufacturing, and, because the canal discharged into the Potomac River, the availability of water was somewhat greater than elsewhere along the canal and not subject to Maryland's prohibition against using the water for milling grain. [60] The amount of power generated by water flowing in the Potomac was even less than the horsepower generated by canal water. C&O Canal Dam 3 had originally diverted water to power the United States Arsenal at Harpers Ferry and downstream, at Weverton, Maryland, the Weverton Manufacturing Company had harnessed the Potomac in 1834 to power a factory and two mills. At Dam 5, the "Honeywood Mill" had drawn water from the river for power generating purposes as early as 1837. [61]

Fifty years later, however, the United States Census of

Manufactures found only one operating water powered mill on the entire Potomac River, a fact described by the Census Bureau as "very remarkable considering there are several large falls." One mile east of Shepherdstown, a cement mill obtained approximately 50 horsepower from the Potomac. The Honeywood Mill at Dam 5 was inactive, the mills at Weverton were abandoned, and the Harpers Ferry Arsenal had been destroyed during the Civil War. [62] During the 1890s, the Shenandoah Pulp Company's plant at Dam 3 used the Potomac River to generate, depending upon the volume of flow, between 350 and 1,000 horsepower, however a survey of the river in 1906 again found only one active water power user, the mill at Dam 5. [63] With control of the Potomac River in the hands of the Chesapeake and Ohio Canal Company, the river made a miniscule contribution to powering industry along its right of way. The C&O Canal Company never developed even the Potomac's minimum potential waterpower much less the 170,620 horsepower maximum.

The Chesapeake and Ohio Canal retarded the growth of water powered industry along the Potomac, but, like the railroads, stimulated the coal trade. Coal, the primary commodity transported on the C&O Canal, offered manufacturers a plentiful and relatively inexpensive source of fuel. The Potomac River, given its highly variable flow and its control by the Canal Company, proved to be a far less reliable, less convenient, and a less easily developed and utilized source of industrial power than coal fired steam engines. [64] The extreme fluctuations of flow, floods, freshets, lack of natural storage, use of all but "surplus" water by the canal, lack of guaranteed head or volume, and the availability of a plentiful supply of West Virginia and Maryland coal as an alternative fuel effectively precluded the use of the Potomac River for powering manufacturing and milling.

THE GROWTH OF TOWNS AND CITIES IN THE POTOMAC RIVER VALLEY

The Chesapeake and Ohio Canal did spawn and sustain a number of towns along its right of way. Williamsport, Hancock, Oldtown, and Westernport, Maryland, and Shepherdstown, West Virginia channeled traffic to and from the canal and supplied the needs of the Canal Company and canal boatmen. The major cities of the upper Potomac River Valley, Hagerstown and Cumberland, Maryland, and Martinsburg, West Virginia, rose to prominence because of their proximity to an abundant supply of raw materials, such as coal, limestone, and cement, the use of the water power available on numerous small streams, and the arrival of the Baltimore and Ohio Railroad during the middle of the nineteenth century.

Water power, extremely limited on the Potomac River and the Chesapeake and Ohio Canal, was, however, developed to a much greater extent on the secondary tributaries. By 1880, Berkeley County, West Virginia tallied a minimum of 32 water powered saw, flour, and grist mills utilizing a minimum of 478 horsepower. To the east, in neighboring Jefferson County, water power provided 31 flour, saw, and even woolen mills with 448 horsepower. Outside of these two West Virginia counties, other small Potomac River tributaries generated 1,412 horsepower used by almost 100 mills. Across the Potomac, in Maryland, flour, saw, paper, and furniture mills, as well as blast furnances and agricultural implement producers, used water power extensively. By 1880, in Hagerstown and surrounding Washington County, Maryland, at least 70 establishments generated 1,614 horsepower using water power and to the east, in Frederick County, Maryland, 107 enterprises used water to generate 1,980 horsepower. Further west, in Allegany and Garrett counties, water power supplied 24 mills with 500 horsepower. [65]

Ample timber, animal husbandry, a variety of fruit and grain crops, and the water power available from the small streams sustained a multitude of grist, flour, and saw mills, tanneries, and distilleries. Consequently, until after 1870, agriculture and associated water powered mills dominated the economy of Berkeley County, West Virginia and its leading city, Martinsburg.

THE RAILROAD'S CONTRIBUTION TO INDUSTRIAL DEVELOPMENT

The arrival of the railroad altered the balance between agriculture and industry. The Baltimore and Ohio, pushing west from eastern Maryland, reached Martinsburg in 1841. In 1866, the railroad designated the city a division point and constructed large machine and repair shops. Within another four years, the Baltimore and Ohio employed more than 200 men in the Martinsburg shops and annually dispensed $120,000 in wages to these workmen. The Cumberland Valley Railroad, with connections in Harrisburg, Pennsylvania to the vast Pennsylvania Railroad, arrived in Martinsburg in 1873 en route to a Virginia connection with the Chesapeake and Ohio Railroad. In addition to expanding employment and pumping a sizeable payroll into the local economy, the railroad lines running north and south, as well as east and west, gave the products of Berkeley County's farms, orchards, and quarries access to all the major eastern and mid-western markets, and offered entrepreneurs a highly desirable location for large new mills and factories. [66]

The railroads, however, proved to be a mixed blessing. The same changes that heralded the arrival of industry and prosperity contributed to the economic violence that erupted in 1877 when Baltimore and Ohio Railroad employees at Martinsburg began a railroad strike that spread across the nation. In Martinsburg, the immediate consequences of the 1877 strike were the destruction of the railroad's property and the city's elimination from the competition for designation as the West Virginia state capital. Adverse long term economic consequences were hardly noticeable.

By 1890, industrial prosperity and tranquility had seemingly returned. Collectively, the Baltimore and Ohio and the Cumberland Valley Railroads employed more than 1,000 men in Martinsburg and dispensed over $40,000 in wages each month. In addition to the railroads, 42 manufacturing establishments, with $84,225 in machinery, employed approximately 460 workmen whose wages in 1890 totaled $163,106. Berkeley County's population grew 50 percent, from a pre-Civil War level of 12,525 in 1860 to 18,702 by 1890. Martinsburg accounted for more than 8,000 of the 1890 county population total, up from 6,000 in 1880 and 3,000 in 1860. [67] Real estate values in Martinsburg climbed thirty three and one-half percent in the years between 1888 and 1890 and this encouraged a major boom in housing construction. [68] Construction of a $125,000 United States District Court building and local incentives such as property tax abatements and free water for new manufacturing establishments further contributed to the city's robust industrial development. [69] Even the agricultural depression beginning in the late 1880s, visible in the decline in the value of Berkeley County's farm goods from $886,485 in 1880 to $693,760 in 1890, benefited Martinsburg's industrial growth. [70] Falling agricultural prices provided a strong inducement for shifting investment from agriculture to industry and encouraged marginal farmers to migrate to the city and accept factory employment.

Unbridled optimism pervaded the frequent expressions of "boosterism" appearing in the local newspapers. The Martinsburg Independent, for example, editorialized:

> Yes, yes! Martinsburg has schools, churches, banks, mills, foundry, gas and lime plants, planing mills, carriage factories, other manufacturing interests already established and now in progress, and the best of artisans, merchants, good citizens, and pretty women, and we defy the world to keep our town from going ahead. We are sure to keep in the front rank in going ahead to success. [71]

FOOTNOTES: CHAPTER I

[1] Maryland Geological Survey, Maryland Geological Survey Volume X (Baltimore: The Johns Hopkins Press, 1918), pp. 90-96; United States Geological Survey, Twenty-First Annual Report 1899-1900, Part 4 (Washington, D.C.: Government Printing Office, 1901), p. 99; United States Geological Survey, Nineteenth Annual Report 1897-1898, Part 4 (Washington, D.C.: Government Printing Office, 1899), pp. 132, 141; United States Bureau of the Census, Tenth Census of the United States Reports on the Water Power of the United States (Washington, D.C.: Government Printing Office, 1885), pp. 523, 558-559; United States Geological Survey, Water Supply Paper 192 (Washington, D.C.: Government Printing Office, 1907), pp. 7, 20.; A.A. Horton, "Water Power Resources of West Virginia," in Semi-Centenial History of West Virginia, J.M. Callahan, ed. (Charleston, W.V.: Semi-Centenial Commission, 1913), p. 431; West Virginia Geological Survey, County Report: Jefferson, Berkeley, Morgan Counties (Wheeling, W.V.: News Litho Co., 1916), pp. 51. 68-69.

[2] USGS, Annual Report 1899-1900, p. 102; USGS, Water Supply Paper 192, p. 16; Tenth Census, Water Power, pp. 558-559.

[3] USGS, Water Supply Paper 192, p. 7; Tenth Census, Water Power, pp. 558-559.

[4] USGS, Water Supply Paper 192, p. 20.; Horton, "Water Power Resources," p. 431.

[5] USGS, Water Supply Paper 192, pp. 7-8.

[6] MGS, Maryland Geological Survey Volume X, pp. 90, 450; USGS, Water Supply Paper 192, pp. 7-8; Tenth Census, Water Power, p. 558.

[7] USGS, Water Supply Paper 192, pp. 7, 18-20.

[8] Tenth Census, Water Power, p. 40; USGS, Water Supply Paper 192, pp. 252-253. Tenth Census, pages 45-51, contains detailed descriptions of these tributaries.

[9] USGS, Water Supply Paper 192, pp. 9, 182; USGS, Annual Report 1899-1900, p. 102.

[10] Tenth Census, Water Power, pp. 28, 559,565; USGS, Water Supply Paper 192, pp. 34-40; MGS, Maryland Geological Survey Volume X, p. 225; WVGS, County Reports, pp. 98-103.

[11] Ibid, 97-98.

[12] MGS, Maryland Geological Survey Volume X, pp. 9, 70-71, 171, 180; WVGS, County Reports, pp. 35-40.

[13] MGS, Maryland Geological Survey Volume X, pp. 92-94, 181; USGS, Annual Report 1897-1898, p. 134; USGS, Annual Report 1898-1899, pp. 134, 140; USGS, Annual Report 1899-1900, pp. 100-102; WVGS, County Reports, pp. 69-76; Tenth Census, Water Power, p. 527.

[14] Ibid.; USGS, Annual Report 1898-1899, pp. 132, 141; Horton, "Water Power Resources," p. 431; WVGS, County Reports, pp. 53-57.

[15] Tenth Census, Water Power, pp. 530, 558-559, 569; USGS, Annual Report 1899-1900, p. 102; USGS, Water Supply Paper 192, p. 43; MGS, Maryland Geological Survey Volume X, pp. 445-446, 450-451; MGS, Allegany County, p. 234; MGS Garrett County, pp. 275-276; Horton, "Water Power Resources," p. 434.

[16] MGS, Maryland Geological Survey Volume X, p. 444.

[17] USGS, Annual Report 1897-1898, p. 141; Tenth Census, Water Power, pp. 565-569; MGS, Maryland Geological Survey Volume X, p. 446; USGS, Water Supply Paper 192, pp. 43, 66; MGS, Allegany County, p. 244.

[18] MGS, Maryland Geological Survey Volume X, pp. 180, 444-447; USGS, Annual Report 1900, p. 102; MGS, Allegany County, pp. 234, 244-245; USGS, Annual Report 1897-1898, p. 136; Tenth Census, Water Power, p. 569.

[19] USGS, Annual Report 1897-1898, p. 147; MGS, Allegany County, pp. 240-242.

[20] Tenth Census Water Power, pp. 529, 569; USGS, Annual Report 1899-1900, p. 103.

[21] Maryland Geological Survey, Maryland Geological Survey Volume VIII (Baltimore: Johns Hopkins Press, 1905), p. 398.; MGS, Maryland Geological Survey Volume X, pp. 91, 181.

[22] Ibid., pp. 91-92, 98, 125, 460-461; MGS, Allegany County, p. 38; WVGS, County Reports, pp. 38-40, 76-80.

[23] MGS, Maryland Geological Survey X, p. 98; Tenth Census, Water Power, p. 568.

[24] USGS, Annual Report 1899-1900, p. 106; Tenth Census, Water Power, p. 562; WVGS, County Reports, p. 77.

[25] MGS, Maryland Geological Survey Volume X, p. 180.

[26] Walter Sanderlin, The Great National Project (Baltimore: The Johns Hopkins University Press, 1946), pp. 16-17; MGS, Maryland Geological Survey Volume X, pp. 96-97; USGS, Water Supply Paper 192, p. 183; WVGS, County Reports, pp. 79-81.

[27] Sanderlin, Great National Project, pp. 29-44.; Opinion of Attorneys Johnson and Johnson, Baltimore, Maryland, February 16, 1886, in "Potomac Development Volume 1, C&O Canal Company and Potomac River Water Rights," PEC; USGS, Water Supply Paper 192, pp. 183-184.

[28] Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC; USGS Water Supply Paper 192, p. 185.

[29] Sanderlin, Great National Project, pp. 199-200; MGS, Maryland Geological Survey Volume X, pp. 96-97; USGS, Water Supply Paper 192, pp. 185-186; Clarence E. Martin to PEC, March 25, 1931, Dam 4 File, PEC Minor Stations.

[30] Sanderlin, Great National Project, pp. 18-19; John Luzader, "Historic Structure Survey Dam No. 4, Chesapeake and Ohio Canal," National Park Service, pp. 1-2. (Typewritten)

[31] Sanderlin, Great National Project, pp. 113, 118; Luzader, "Historic Structure Survey," pp. 1-5; "Potomac Edison Development Volume 1," pp. 1054-1055.

[32] Sanderlin, Great National Project, p. 210.

[33] Ibid.

[34] Ibid., p. 211.

[35] Ibid., pp. 218-219, 223-224; Lutzader, p. 1.

[36] G.T. Twyford to G.S. Humphrey, November 4, 1933, Dam 4 File, PEC Minor Stations; J.H. Harlow to G.L. Nicolson, March 12, 1913, A.D. Lewis to G.L. Nicolson, November 9, 1933, C&O Papers, NA.

[37] Sanderlin, Great National Project, pp. 241-142.

[38] Ibid., p. 257.

[39] Ibid., pp. 289-290; USGS, Water Supply Paper 192, pp. 317, 327-328; MGS, Allegany County, pp. 266-267.

[40] "Report of the West Virginia Conservation Commission 1908," in West Virginia Geological Survey, Volume 5: Forestry and Wood Industries (Charleston, W.V.: A.B. Brooks, 1911), pp. 22-23.

[41] Ibid., p. 23.

[42] Sanderlin, Great National Project, pp. 276, 289-290.

[43] Ibid., p. 210. The number of floods tabulated from data in Sanderlin, Great National Project, pp. 141, 191, 192-193, 207-208, 210-212, 220, 224, 230-231, 241-243, 253, 256-257, 276-277, 281, 289-290. The floods of 1877, 1881, 1889 are described in USGS, Water Supply Paper 192, pp. 179-182.

[44] Sanderlin, Great National Project, 192, 210, 220, 231-232, 247-248, 289.

[45] Ibid, pp. 192-193; USGS, Water Supply Paper 192, pp. 187-188.

[46] USGS, Annual Report 1899-1900, p. 100; USGS, Annual Report 1897-1898, pp. 134, 141; MGS, Maryland Geological Survey Volume X, p. 446.

[47] USGS, Annual Report 1899-1900, p. 102; USGS, Water Supply Paper 192, p. 182. The same conclusion appears in Tenth Census, Water Power, pp. 559-560.

[48] Tenth Census, Water Power, pp. 560-563; Horton, "Water Power Resources," p. 433.

[49] Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC; MGS, Maryland Geological Survey Volume X, p. 44.; C.E. Martin to G.S. Humphrey, March 25, 1931, Dam 4 File, PEC Minor Stations.

[50] Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC; C.E. Martin to PEC, March 25, 1931, Dam 4 File, PEC Minor Stations.

[51] Ibid.; G.L. Nicolson to Potomac Public Sevice Company, April 6, 1923, Dam 4 File, PEC Minor Stations.

[52] Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC; Sanderlin, Great National Project, p. 199.

[53] Sanderlin, Great National Project, p. 199.; Acts of the General Assembly of Virginia, 1829, Chapter 77, Section 2, cited in Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC and in G.L. Nicolson to PPSC, April 6, 1923, Dam 4 File PEC Minor Stations.

[54] General Assembly of Maryland, Acts of 1832, Chapter 291,

Approved March 22, 1833, cited in Opinion of Attorneys Johnson and Johnson, Potomac Development Volume 1," PEC; Sanderlin, Great National Project, p. 199.

[55] Acts of the General Assembly of Virginia, February 27, 1829, Chapter 77, Section 2, cited in Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC; G.L. Nicolson to PPSC, April 6, 1923, Dam 4 File, PEC Minor Stations; Sanderlin, Great National Project, pp. 199-200.

[56] Ibid., pp. 162, 166, 198-199; Tenth Census, Water Power, p. 38.

[57] Ibid., p. 201.; Tenth Census, Water Power, pp. 38, 559-560; USGS, Annual Report 1899-1900, p. 103; USGS, Water Supply Paper 192, p. 190.

[58] Sanderlin, Great National Project, p. 200.

[59] USGS, Water Supply Paper 192, p. 190.

[60] Tenth Census, Water Power, p. 560; Sanderlin, Great National Project, p. 201.

[61] Tenth Census, Water Power, pp. 560-565; "Potomac Development Volume 1," pp. 1047-48, 1054-55.

[62] USGS, Annual Report 1899-1900, pp. 105-106; USGS, Water Supply Paper 192, pp. 42-45.

[63] USGS, Water Supply Paper 192, p. 190; USGS, Annual Report 1897-1898, pp. 136-137; USGS, Annual Report 1899-1900, pp. 105-106.

[64] WVGS, Volume 5, p. 25; West Virginia Conservation Commission, Report of the West Virginia Conservation Commission (Charleston, W.V.: Tribune Printing Co., 1909), p. 28.

[65] Tabulated from information listed in Tenth Census, Water Power, pp. 568-571. A detailed listing and description of water power users on the Potomac and Shenandoah Rivers circa 1897 is found in United States Senate Document 90, Fifty-Fifth Congress, Second Session, "Drainage Basin of the Potomac River" and Senate Document 211, "Bacteriological Examination of the Potomac River." Both reports are summarized in USGS Annual Report 1898-1899, pp. 132-160.

[66] The [Baltimore] Sun, January 11, 1901; WVGS, County Reports, pp. 11-13, 17-21; Martinsburg Independent, May 5, 1890.

[67] WVGS, County Reports, p. 20.; United States Bureau of the

Census, Eleventh Census of the United States, 1890 pp. 626-627.

[68] Martinsburg Independent, April 12, May 5, 1890.

[69] Martinsburg Independent, May 5, May 17, 1890.

[70] USGS, Water Supply Paper 192, pp. 327-328.

[71] Martinsburg Independent, May 3, 1890.

CHAPTER II

THE BEGINNINGS OF ELECTRIC POWER

THE EDISON ELECTRIC ILLUMINATING COMPANY OF MARTINSBURG, W.V.

On November 7, 1889, the United Edison Manufacturing Company of New York, attracted by Martinsburg's record of local growth and pervasive spirit of optimism, approached the Martinsburg City Council with a proposal to construct an Edison electric generating plant to supply both public and private users with nightime arc and incandescent lighting. United Edison sought a municipal franchise to erect poles, string transmission and distribution lines, and sell electric lighting at rates equal to the cost of gas illumination. [1]

One week later, adopting the recommendation of its "Light Committee," the Mayor and Council issued the United Edison Company the franchise, subject to stipulations that the generating plant be in operation within one year and that a majority of the stockholders of the corporation holding the franchise be residents of Martinsburg or Berkeley County, West Virginia. Unwilling, or unable, to comply with the second condition, the New York entrepreneurs disposed of the franchise to a group of local businessmen who organized and chartered the Edison Electric Illuminating Company of Martinsburg. [2]

By the second week in December, 1889, the stockholders of the local enterprise had called their first meeting and elected M. W. Martin, President; S. W. Walker, Secretary; and George M. Bowers, Treasurer. The Board of Directors included Martinsburg residents R. Lamon, C. H. Miller, C. J. Faulkner, and G. H. Sencindriver, and two residents of Washington, D. C. [3] The Board of Directors signed a contract with the United Edison Manufacturing Company of New York for a "first class electric plant" [4] The contract specified that every city street illuminated by gas would have electric lights. [5]

To house the generating equipment, the "Schwartz Mill and Mill Lots," encompassing 6.24 acres of land, a two story stone mill building, and the right to draw water from adjacent Tuscarora Creek, was purchased from Treasurer G. M. Bowers and Board of Directors member G. Sencindriver for a total of $5,500. [6] The property, bordering Martinsburg's central business and manufacturing district and lying between the Baltimore and Ohio Railroad and Tuscarora Creek, was an ideal location for a coal fired, steam powered electric generating station. Tuscarora Creek supplied water for the steam boilers and condensers and coal arrived on a B&O Railroad siding next to the plant. At a cost of

$10,000 the company added two smaller brick buildings onto the old stone mill. The two additions, an engine room and a boiler room with a large brick smokestack, permitted the electric generating machinery to be placed in the old Schwartz Mill building with sufficient space for future expansion of generating capacity. [7]

P. W. Cadugan, an agent of the United Edison Electric Company of New York, arrived in Martinsburg in January 1890 to superintend the installation of the generating equipment and the erection of the light poles and distribution system. Construction progressed rapidly and, by the end of February, workmen had completed stringing transmission lines and constructing the two brick buildings and tall smokestack adjoining the original Schwartz Mill. [8] Photograph WV-27-1 illustrates the Schwartz Mill before the building was converted into an electric generating plant.

At the end of March, as the generating equipment began to arrive, electricians had most of the downtown stores wired for lights. The company strove to begin generating electricity before April, however, a delay in the arrival of one of the plant's two steam engines postponed the beginning of operations until mid-April. [9] On April 10, with assistance from the Martinsburg Fire Department, the Edison Electric Illuminating Company of Martinsburg filled and fired up the boilers, tested the performance of the steam engines, and reported that the machinery was in "perfect order." [10]

The introduction of electricity fascinated and excited the residents of Martinsburg and on April 16, attracted by the "glare through the skylights" of the generating station, an "immense crowd" gathered to witness the successful first test of the arc lights inside the generating plant. [11] Three nights later, residents of Martinsburg and visitors from across Berkeley County crowded into the city, "from one end to the other," to observe a test of the street lamps. [12]

The Edison Electric Illuminating Company of Martinsburg began commercial operations using two 125 horsepower steam boilers and two McIntosch-Seymour double compound, condensing, high speed engines. Each engine, operating under a steam pressure of 110 pounds per square inch, produced 100 horsepower and turned twin driving wheels at 220 revolutions per minute. Each driving wheel of the first engine was belt connected to a 40 kilowatt, Edison "Type 10" alternating current generator capable of illuminating 900 sixteen candlepower (70 watt) incandescent lights. A single Edison-Sperry arc-light generator, with a capacity of 25 two thousand candlepower (450 watt) arc lights was connected to the second steam engine. The switchboard consisted of two voltage indicators, two ampere meters, a ground detector, and a voltage regulator for each generator. [13] Illumination of an unspecified number of private residences and almost all of Martinsburg's with Western Electric. [27] To attract the capital needed to renovate the generating plant, the Mayor and Council repealed the 1889 ordinance requiring that a majority of the electric company's stockholders be residents of Martinsburg or Berkeley County. [28]

At the auction, three Martinsburg residents, William Tebo and two brothers, P. F. and J. H. Rimel, purchased the assets of the Edison Electric Illuminating Company from bankruptcy receiver Stuart Walker for $6,000. [29] After much debate and, apparently, after receiving assurances from the new management that improvements would be made immediately, the Mayor and Council finally agreed to renew the public lighting contract with the local Edison Electric Company, but only for six months. [30] Tebo had agreed to purchase a 45 kilowatt, 2,200 volt alternating current generator with a nominal capacity of 900 incandescent lights from the Westinghouse Electric and Manufacturing Company of Pittsburgh, Pennsylvania. [31]

Frequent power failures during the latter part of 1895 reemphasized the need for increased generating capacity and more modern, efficient equipment. Tebo publicly apologized for the poor service, promised rapid improvements, and announced that the Westinghouse generator would be in service during November. In December, however, the generator had not yet arrived and the failure of one of the electric company's two steam engines left Martinsburg merchants without lights during the height of the Christmas shopping season. Three weeks later, with incandescent lighting demand exceeding the capacity of the alternating current generators, the lights failed once again. [32]

THE INCORPORATION OF THE MARTINSBURG ELECTRIC LIGHT COMPANY

At the beginning of 1896, economic conditions began improving and local industry began expanding once again. Tebo realized that if all of Martinsburg's mills and factories were to install electric lighting, as the Crawford Woolen Company had done in February of 1896, [33] reliability had to be significantly improved and capacity greatly expanded. To finance the improvements and expansion needed to accomodate the electrification of the mills, Tebo purchased the Remil brother's share of the electric company, joined together with a new group of local businessmen, and incorporated the Martinsburg Electric Light Company. The first stockholder's meeting, held on April 7, 1896, elected Tebo as President; W. W. Houseworth, Secretary; and F. E. Wilson, Treasurer. [34] The first action of the Board of Directors was to approve the purchase of a much needed, more powerful steam engine and $1,232.50 was immediately allocated to acquire a 150 horsepower engine from the Taylor Engine Company. This engine was installed and connected by belts to the two 45 kilowatt Edison alternating current generators. With the purchase of the new engine, the Martinsburg Electric Light Company operated three steam engines and four electric generators. [35] Figure 6 illustrates the changes in and the growth of the generating equipment at the Martinsburg electric generating plant. To improve the municipal arc lighting service, Tebo's company added a Royal E. Ball Company arc light generator capable of illuminating 80 two thousand candlepower (450 watt) arc lights. The new equipment assured a more dependable supply of electricity and gave the Martinsburg Electric Light Company the capacity to illuminate as many as 2,700 incandescent and 105 arc lights. [36] (Photograph HAER WV-27-3 illustrates the interior of the Martinsburg Electric Light Company generating station in 1896. The Taylor engine, belted to the two 40 kilowatt Edison alternating current generators appears at the right and toward the rear of the photograph. A McIntosch-Seymour engine, belted to the Ball 80 arc light generator, appears in the center of the photograph. At the left and in the foreground of the photograph the second McIntosch-Seymour engine is seen connected to the 45 kilowatt Westinghouse alternating current generator and the Edison-Sperry arc light generator. The switchboard appears in the center of the extreme left side of the photograph.)

Between 1896 and 1900, the Martinsburg Electric Light Company received a small return on its invested capital. Gross income averaged approximately $1,200 per month, and expenditures for operations and maintenance, taxes, insurance, new equipment, and payments on the principal and interest of $12,500 worth of bonded indebtedness, left the company with small monthly profits ranging between 100 and 450 dollars. [37] Occasionally, the purchase of new equipment necessitated levying assessments upon stockholders. In 1898, a ten percent assessment, yielding $3,000 was levied to permit the purchase of a larger steam engine and an additional arc light generator. The Board of Directors, after considerable debate regarding the need for additional capacity, agreed to purchase a 400 horsepower, 22 by 18 inch, four valve steam engine built by the Fischer Foundry and Machine Company. [38] The purchase price of the engine was $2,450 in cash plus the 150 horsepower Taylor engine, which the electric company subsequently chose to retain. In addition to the Fischer engine, Martinsburg Electric also acquired a second Ball arc light generator rated at 125 lights of 2,000 candlepower each, and agreed to have the smaller 80 light Ball arc light generator removed from the Martinsburg plant and repaired by the manufacturer. [39]

All of the equipment acquired in 1898 was purchased from the Rumsey Electric Machinery Company, a Philadelphia, Pennsylvania distributor of electrical machinery established in 1895 by two brothers, George A. and Eugene A. Rumsey. Both brothers had attended Cornell University; Eugene graduating as an electrical engineer and George, after completing two years, leaving in 1889 to work for the Wilmington (Delaware) Electric Company. As manufacturers' representatives, the Rumsey brothers distributed and installed central station electrical equipment manufactured by the Warren Electrical Manufacturing Company of Sandusky, Ohio; the Pittsburgh Transformer Company of Pittsburgh, Pennsylvania; and the Sangamo Electrical Company of Springfield, Illinois. Eugene designed both central and isolated electric generating stations and managed the Philadelphia office while George, using the experience acquired during his employment with the Wilmington Electric Company, negotiated the contracts and supervised the installation of the equipment. The company, specializing in the installation of electric generating stations outside of large urban areas, competed "successfully and aggressively" throughout the mid-Atlantic states of New Jersey, Pennsylvania, Maryland, Virginia, and West Virginia. [40] The relationship that developed between the Rumsey brothers and both the Martinsburg Electric Light Company, and the company's corporate successors, was a long and mutually beneficial one, despite its acrimonious termination in the face of financial duress.

GROWTH IN THE EARLY TWENTIETH CENTURY

The Martinsburg Electric Light Company entered the twentieth century on a relatively sound financial footing with some new equipment and new management. Assets totaled $28,678.50, of which almost $27,000 represented the value of the Martinsburg generating plant. Liabilities included stock valued at $30,000 and bonded indebtedness of $12,500. [41] Dr. S. N. Myers, a prominent Martinsburg physician, President of the Merchants and Farmers Bank of Martinsburg, and a member of the utility's Board of Directors since 1897, replaced William Tebo as President and Chairman of the Board of Directors of the Company in April 1899. One of Myer's first acts was to hire H. B. Shoemaker, a Chambersburg, Pennsylvania engineer, as "mechanical manager" to superintend the increasingly complex operations and growing workforce at the Martinsburg electric generating plant. [42]

The earnings of the Martinsburg Electric Light Company improved significantly during 1900 and gross income as large as $1,700 per month was reported. [43] This dramatic improvement resulted largely from the inauguration of daytime electric light and power service in March 1900. The simultaneous installation of electric meters, allowing a switch from flat rates to monthly metered kilowatt hour charges, also helped improve the electric company's earnings. [44] To accomodate the increased demand for electricity stemming from the initiation of "day current," a 200 kilowatt, 2,200 volt, three phase, 60 cycle alternating current generator manufactured by the Warren Electric Manufacturing Company, was purchased from the Rumsey Electrical Machinery Company and installed in the Martinsburg generating plant. [45] The Warren generator replaced the two original 40 kilowatt Edison alternating current generators (see Figure 6) and added 120 kilowatts of additional output to the Martinsburg generating plant. With the memory of the electric company's 1896 problems with unreliable service still in the public's mind, the installation of a modern generator to provide increased output was a prudent decision that encouraged commercial and industrial customers to electrify their businesses. The Shenandoah Pants factory, for example, installed electric cloth cutting machinery within one month after the initiation of the day time electric service. [46]

The mechanization of local industry accelerated after 1890. The value of the machinery used in Martinsburg's mills and factories, for example, increased 517 percent between 1890 and 1900, from $84,225 to $519,291. [47] With the dependence upon machinery continuing to grow, sales of electric power to mills, factories, and even quarries emerged as a potentially lucrative new market and the Martinsburg Electric Light Comapny began searching for an inexpensive, reliable, and accessible source of additional generating capacity to serve the new industrial customers. Figures compiled by the West Virginia Geological Survey during the early 1900s illustrate the economic advantage of using electric power in industrial operations. [48] A Berkeley County quarry producing 3,000 tons of limestone per day, for example, could reduce production costs as much as $10,700 annually by using electric rather than steam powered derricks, hoists, air compressors, and pumps.

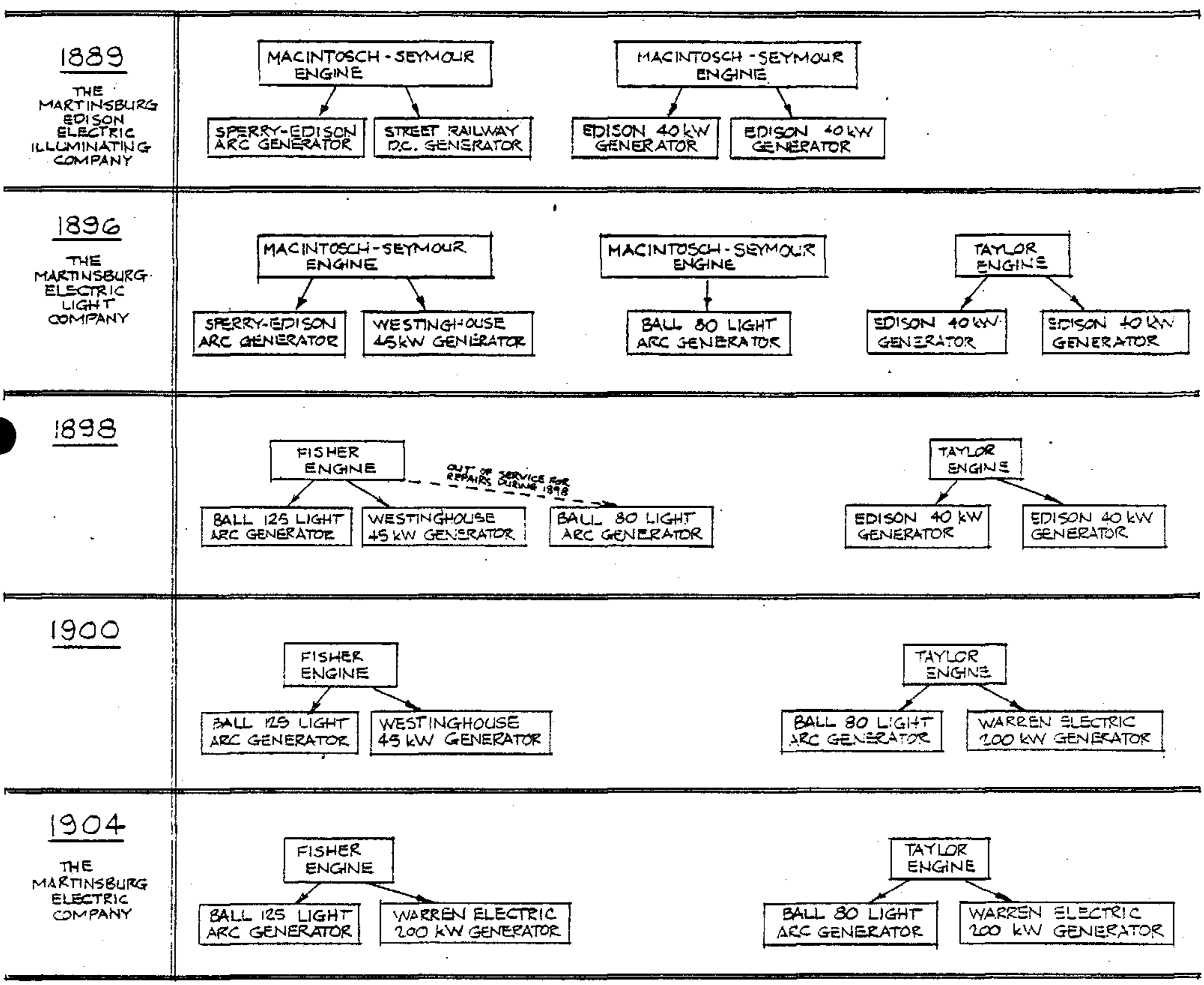
A steam plant at the quarry would have cost approximately $50,000. Annual fixed charges on the equipment would have amounted to 13.5 percent of the investment and included:

depreciation (20 years)	5.0%
interest	6.0%
taxes	1.0%
repairs	1.5%
total	13.5%

The dollar value of the fixed charges on the $50,000 steam plant would have equalled $6,750 per year or $22.50 a day (calculated at the equivalent of 300 ten-hour days per year). Steam boilers would have consumed 14 tons of coal during 10 hours of operation and banking the fires each night would have required an additional 4.9 tons of coal. At $2.80 a ton, delivered to Martinsburg from Cumberland, Maryland, $52.92 worth of coal would have been consumed each day. Operating costs, primarily the wages of an engineer and at least one fireman, but also small amounts of oil and miscellaneous supplies, would have amounted to approximately $4.10 per day. Fixed, fuel, and operating costs associated with a steam plant would have totalled $79.52 a day or 2.65 cents per ton

FIGURE 6

CHRONOLOGY OF MARTINSBURG POWER PLANT GENERATING EQUIPMENT



of limestone quarried and processed.

A steam turbine electric plant at the quarry and the electric motors needed to operate the excavating and processing equipment would have cost approximately $60,000. With annual depreciation, interest, taxes, and repair costs amounting to 13.5 percent of the value of the equipment, and labor costs equal to those of the steam plant, but with coal consumption averaging only 12 tons per day, daily costs would have averaged $64.70 or 2.16 cents per ton of quarried limestone.

Electric motors acquired separately from a steam generating plant and using purchased electricity would have cost approximately $15,000. Calculating annual fixed costs at 13.5 percent of the cost of the equipment and substituting an electrician for an engineer and fireman, fixed and operating costs would have totalled $10.85 a day. The electric motors required to excavate and process 3,000 tons of stone each day would have consumed approximately 1,650 kilowatt-hours of electricity. At two cents per kilowatt-hour of electricity, a common price for electricity sold in large volume during the early 1900s, electricity would have cost $33.00 per day, and total fixed, fuel, and operating costs would have averaged $43.85 per day or 1.46 cents per ton of limestone. Table 6 illustrates these savings.

THE FIRST POTOMAC RIVER HYDROELECTRIC PLANT

The opportunity to offer quarries, manufacturers, and other industrial customers savings as impressive as these was the primary stimulus to the expansion of the Martinsburg Electric Light Company in the years after 1900. In looking at ways to expand generating capacity, Martinsburg Electric examined the water power potential of the Potomac River, despite the river's erratic, frequently unpredictable flow, and the large initial investment that a hydroelectric plant required. The electric company's management realized, however, that unlike a coal-fired steam-driven electric generating station, less labor was normally needed to operate a hydroelectric plant and the fuel costs were small, often nonexistent, and relatively constant.

With control of the Potomac River securely in the hands of the Chesapeake and Ohio Canal Company, constructing a new dam would have not only been costly, but also difficult, if not impossible, to arrange. In the vicinity of Berkeley County, the only site along the Potomac where water power had previously been harnessed was at Dam 5, seven miles upstream from Williamsport, Maryland and twelve miles north of Martinsburg. Here, Edward Colston had constructed a water-powered mill on the West Virginia side of the river in 1835. When the Canal Company acquired control of the

TABLE 6

COMPARATIVE COST OF STEAM AND HYDROELECTRIC POWER

	Steam Plant		Steam/Electric Plant		Purchased Electricity	
Initial Investment	$50,000		$60,000		$15,000	
Costs:	Per day	Annual	Per day	Annual	Per day	Annual
Fixed	$22.50	6,750	27.00	8,100	6.75	2,025
Operating	$ 4.10	1,230	4.10	1,230	4.10	1,230
Fuel	$52.92	15,876	33.60	10,080	33.10	9,900
Total	$79.52	23,856	64.70	19,410	43.85	13,155
Cost per ton of stone	2.656 cents		2.156 cents		1.461 cents	

Source: WVGS, County Reports: Jefferson, Berkeley, Morgan Counties, pp. 598-600.

Potomac in 1837, Colston was permitted, for an annual fee of 100 dollars, to continue drawing surplus water from Dam 5 for use at his mill. [49]

In 1887, the Potomac Pulp Company, a Pennsylvania corporation, purchased Colston's mill and, with his 13 acres of property, the right to draw water from behind Dam 5. Although pulp grinding at the site had ceased sometime around 1891, all of the mill's hydraulic equipment, including three vertical shaft turbines, remained intact and operable, although in need of repairs. [50] Because of its proximity to Martinsburg and its convertibility, Martinsburg Electric Light viewed the Potomac Pulp Mill at Dam 5 as a highly desirable site for a hydroelectric plant (see photographs HAER WV 28-1 & 2 for views of the mill).

Almost a full year of financial and legal maneuvering preceeded the decision to expand. In February of 1901, a local newspaper reported a "considerable change in the holdings of stock in the Martinsburg Electric Light Company," had concentrated ownership among a small number of stockholders. [51] Shortly thereafter, the owners of the Potomac Pulp Company began exploring the legality of resuming operations at Dam 5 after ten years of inactivity. Representing the owners of the Potomac Pulp Company, S. A. Williams, President of the Harford County National Bank in Bel Air, Maryland, inquired of Baltimore attorney John P. Poe:

> Has the owner of the Colston Mill site at Dam No. 5 on the Chesapeake and Ohio Canal, (Berkeley County, West Virginia) the right to use the surplus water flowing over the dam at that point for milling and power purposes?
>
> Suppose the Chesapeake and Ohio Canal should be abandoned, what rights would the owner of said mill site have to Dam No. 5; could he maintain it and use the water for the purposes above mentioned? [52]

Poe assured Williams that, despite having curtailed pulp grinding operations at the mill in 1891 and having failed to pay the annual water rent since that date, no legal prohibition precluded resuming operations at the site so long as the Potomac Pulp Company had not "repudiated" its original contract with the Chesapeake and Ohio Canal Company. Poe did suggest that a resumption of activity at the site might involve a financial liability for the unpaid water rent of the previous ten years. [53]

Responding to William's second question, the attorney concluded that the Canal Company could neither "be compelled to maintain the dam for the benefit of your clients," nor did it have a right to "destroy the dam" and thus abrogate rights originally acquired by Colston and subsequently legally transferred to the Potomac Pulp

Company. Poe also advised Williams that the dam could not be altered or raised. [54] With the assurance that the Potomac Pulp Company possessed the right to resume drawing water from behind Dam 5, S. A. Williams and Dr. Myers proceeded to bring Potomac Pulp and Martinsburg Electric Light together to undertake the construction of a hydroelectric plant.

CONVERSION OF THE MILL AT DAM 5

The public first became aware of the joint effort being undertaken at Dam 5 in February 1902 when the Martinsburg Herald reported that the Hagerstown, Maryland city engineer had visited the site to consult with Martinsburg Electric Light's engineer Shoemaker about the project. [55] Thereafter, newspapers trumpeted the participation of Bel Air, Havre de Grace, and Baltimore, Maryland and Carlisle, Hanover, and Philadelphia, Pennsylvania "capitalists" and "moneyed men" in the project. The newspaper articles described the proposed hydroelectric plant as the future source of electric light and power for manufacturing plants as far away as Hagerstown, Maryland and Winchester, Virginia, and for trolley lines in Hagerstown, Antietam, and Williamsport, Maryland and Martinsburg, Shepherdstown, and Harper's Ferry, West Virginia. A visit to Dam 5 by George Burbank, a hydraulic engineer associated with the 1895 Niagara Falls, New York hydroelectric plant prompted one local reporter to very boldly, and somewhat mistakenly, declare in print: "The plant at Dam No. 5, when it is in operation, will be second only in size and strength to the immense Niagara Falls power plant." [56]

With the help of consulting engineers such as Burbank, engineer Shoemaker assessed the condition of the mill's existing hydraulic equipment, selected the electrical generating equipment to be installed, and calculated the cost of converting the old pulp grinding mill into a hydroelectric plant.

To undertake the project, the Board of Directors of the Martinsburg Electric Light Company and representatives of Potomac Pulp formed a new corporation, the Martinsburg Power Company, in June of 1902. Chartered in Berkeley County, West Virginia, the Martinsburg Power Company issued $115,000 of stock. Dr. Myers was elected President of Martinsburg Power and S. A. Williams was named Vice-President. H. B. Shoemaker was named Chief Engineer. [57] In April 1903 Martinsburg Power purchased the 13 acres of property adjacent to the West Virginia abutment of Dam 5, but not until May 1904 did the power company legally acquire the assets of the Martinsburg Electric Light Company. To finance construction of the Dam 5 plant and the acquisition of the Dam 5 property and the Martinsburg generating plant, Martinsburg Power sold $150,000 worth of five percent interest bearing, 20 year maturity first mortgage bonds. [58]

The construction of a hydroelectric plant at Dam 5 was the largest, but not the exclusive element of a major restructuring of the operations of the Martinsburg Power Company. The company intended to rely on the electricity generated at Dam 5 to satisfy demand whenever possible and use the steam-driven generators at the original Martinsburg electric plant to augment the electricity produced at Dam 5 or when the hydroelectric plant was unable to meet customer demand. As construction at Dam 5 was beginning, the Martinsburg generating plant was already undergoing alteration. A fifteen ton Warren Electric Manufacturing Company, 200 kilowatt alternating current generator was installed and connected to the 400 horsepower Fischer engine purchased in 1898. The total output of the two Warren generators, 400 kilowatts, provided adequate capacity should the Dam 5 plant be inoperable for any reason. The combination of the hydroelectric plant, designed to produce 450 kilowatts by itself, and even one of the Warren 200 kilowatt generators housed in the Martinsburg plant assured that adequate capacity was available to meet any increase in demand "for years to come." [59] Figure 6 illustrates the growth of the Martinsburg electric plant from 1889 to 1904 (see photograph HAER WV-27-4 for a view of the Martinsburg plant circa 1904).

Construction at Dam 5 began in 1903 after engineer Shoemaker chose to retain the pulp mill's three S. Morgan Smith Company, 66 inch diameter vertical shaft turbines installed prior to 1890. Each turbine, operating at 190 revolutions per minute under a 14 foot net head of water, produced up to 250 horsepower. The three wheels, arranged in a line parallel to the Potomac River, were geared to a single horizontal wooden line shaft (see Figures 7 and 8). Two of the three water wheel wicket gates were connected to a Repogle relay governor using a grooved pulley and steel cables. The third water wheel had a manually operated wicket gate and was used only when the load was larger than the combined capacity of the other two turbine wheels or when repairs required removing one of the other wheels from operation. [60]

The desire to use the existing mill building without major structural alterations and to avoid having the generating equipment submerged during floods and freshets resulted in a somewhat unique arrangement of the equipment inside the building. A heavy timber structure was erected within the building to elevate the generator, exciter, governor, and switchboard 30 feet above the normal tailwater level. [61] The "certainty" that the mechanism linking the horizontal line shaft to the generator would be either partially or totally under water during a flood or freshet prompted the use of rope drive. [62] Rope drive was not only deemed "likely to give the least amount of trouble" when submerged, [63] but also permitted the use of a high speed horizontal shaft generator without using additional bevel gears

FIGURE 7

HYDRAULIC EQUIPMENT, 1904 DAM 5 HYDROELECTRIC PLANT

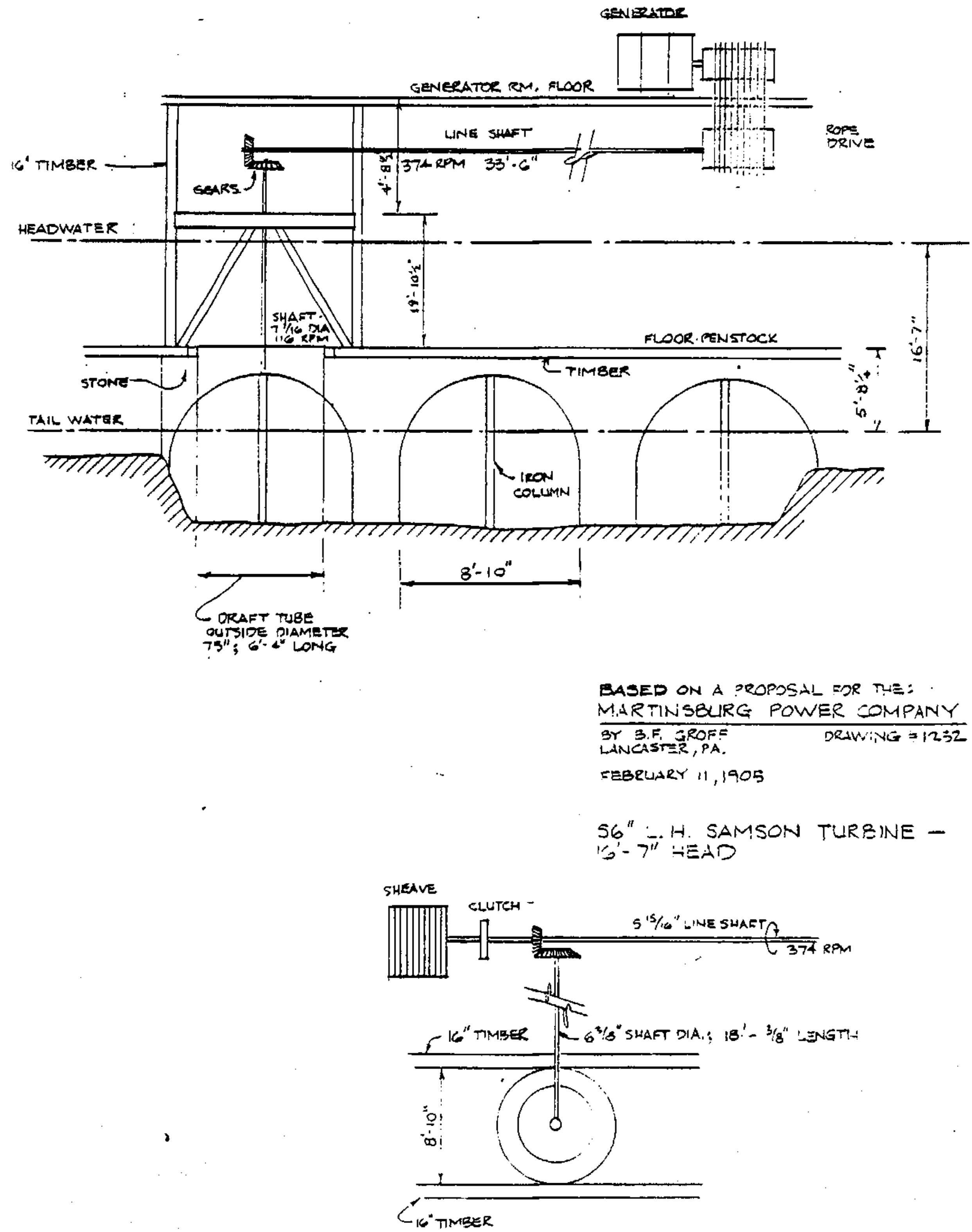
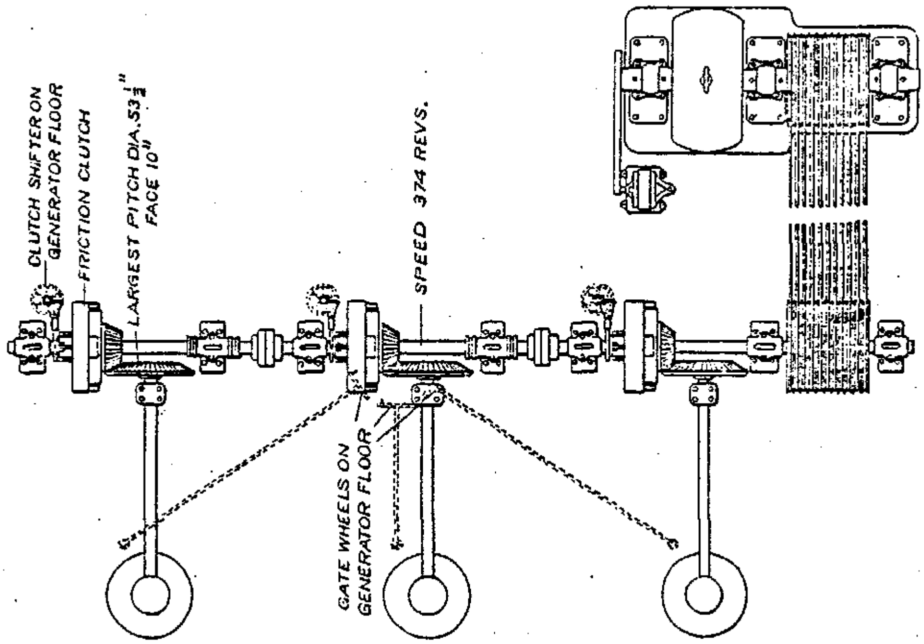
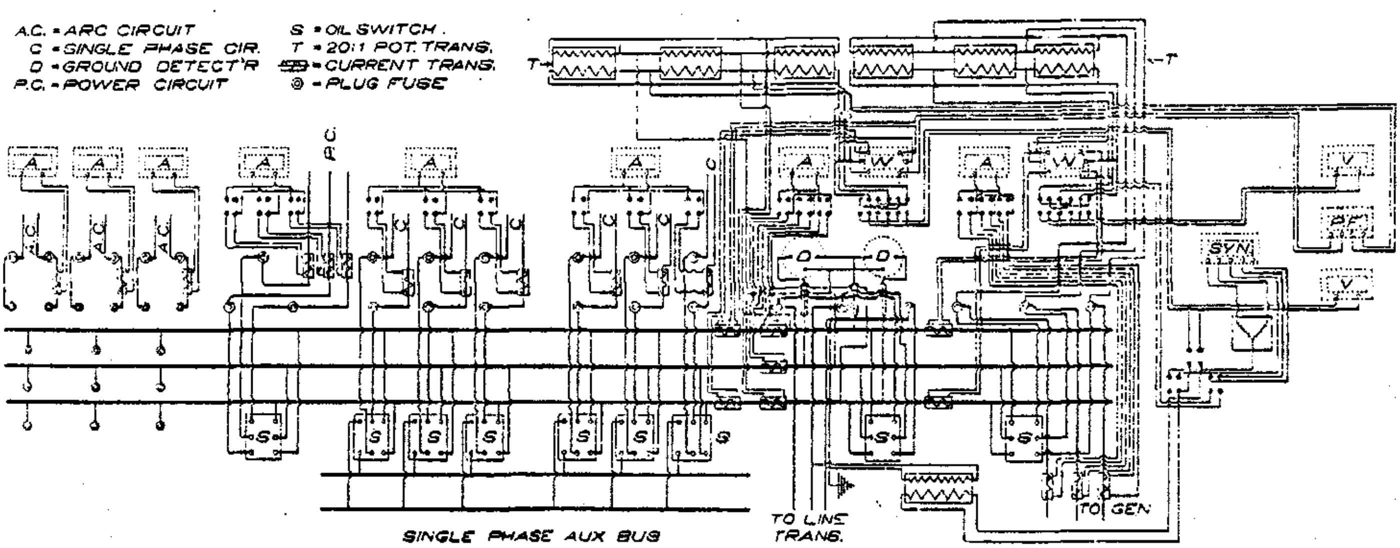


FIGURE 8

DAM 5 PLANT WATER WHEELS, SHAFTING, AND ROPE DRIVE (1904)



DAM 5 SWITCHBOARD (1904)



Source: A.E. Buchenberg, "A Recent High Tension Installation," The Engineer 4 (February 15, 1905).

and vertical wooden shafting that would have reduced the horsepower available at the generator by as much as 15 percent. [64] In addition to minimizing friction losses, withstanding immersion, and elevating the generating equipment high above the reach of floods and the moisture of the open water wheel pits, rope drive had several other merits: compared with gears and shafts, rope drive cost less to install and maintain, produced much less noise, occupied less space, and transmitted fewer vibrations to the timber structure supporting the generating equipment. At the Dam 5 plant, Shoemaker used the American continuous rope drive system rather than the English multiple rope system. With the American system a continuous length of rope with a single splice was repeatedly looped around two sheave wheels with multiple grooves. The English rope drive system used a separate loop of rope for each individual sheave wheel groove. [65]

A single 450 kilowatt, 60 cycle "Y" connected, three-phase alternating current Warren Electric Manufacturing Company generator was installed in the Dam 5 plant. Operating at 360 revolutions per minute, the generator produced 2,200 volts. A four pole compound wound, seven and one-half kilowatt, 125 volt, Warren Electric exciter, operating at 1,150 revolutions per minute, was belt-connected to the generator shaft. [66] (The generator, exciter, and rope drive pulley appear in photograph HAER WV-28-3.)

A marble operating and control board housed the alternating current ampmeter, a three-phase kilowatt meter, two single-phase 12,000 volt static lightning arresters connected for three-phase operation, an exciter field rheostat, and a double-pole carbon break exciter switch. A separate marble panel board contained the volt, power factor, and frequency meters. Ten feet behind the operating board was a switchboard with the high-tension transformers, three Westinghouse single pole air break switches, a set of three General Electric 12,000 volt lightning arresters, and a "Condit" three-phase 15,000 volt oil switch connected to a handle on the operating board. The separation of the switchboard and operating board insured the safety of the operator of the equipment. [67] (The operating board and engineer Shoemaker appear at the right of photograph HAER WV-28-4. At the left of the photograph is the Replogle relay water wheel governor.)

The Dam 5 hydroelectric plant was linked to the electric generating plant in Martinsburg by a 12 mile long, 12,000 volt, copper wire, high-tension transmission line constructed along both public roads and a private right of way. Thirty-five foot long chestnut poles with double crossarms were spaced at 90 foot intervals and, to protect the line and permit repairs to be made without interference from vegetation, the land on both sides of the poles was cleared for a distance of fifty feet (see photo HAER

WV-28-5). [68]

At Martinsburg, a separate brick substation building, detached from the generating station, was constructed to house the step-down transformers, oil switches, ground detectors, and lightning arresters. The control rod for the substation's oil switches entered the main generating building through an underground conduit. The incoming current was delivered to three 150 kilowatt oil cooled Pittsburgh Electric Company transformers, each wound for 1,100 to 2,200 volts and connected in "delta" to permit operation at two-thirds load should one of the transformers fail. [69]

Current generated by both the Dam 5 hydroelectric and Martinsburg steam plants was distributed through a seven foot high, eighteen foot long, seven panel switchboard. A separate indicator board housed the voltmeters, synchroscopes, and power factor meters for both the Dam 5 and Martinsburg generators. A. E. Buchenberg, writing in the February 1905 issue of The Engineer, described the seven panel switchboard in detail:

> On panel 1, the exciter panel, are mounted the direct-current exciter ampmeter, a double-pole, carbon break exciter switch, and field and series exciter rheostats.
>
> On panel 2, controlling the belt driven generator are mounted a three-phase indicating wattmeter, an alternating-current ampmeter, phase changing plugs, three Warren plug fuses, and a three-pole, single throw Condit oil switch.
>
> On panel 3, known as the water power panel, are mounted a three-phase indicating wattmeter, an alternating-current ampmeter, phase changing plugs, two single-phase, 2,300 volt static ground detectors connected for three-phase operation, three plug fuses, and operating handles for the high-tension oil switch, and the three-pole, single-throw oil switch.
>
> Panels 4 and 5 are in duplicate and control the six incandescent lighting circuits. On each panel are mounted an alternating-current ampmeter with plugs for reading the current on each circuit, six plug fuses, and three double-pole, double-throw oil switches.
>
> On panel 6, [controlling the second belt driven Warren Electric alternating current generator] are mounted an alternating-current ampmeter with plugs, three-phase plug fuses, and a three-pole, single throw oil switch.
>
> Panel 7 controls the three Helios-Upton, series arc lighting circuits, and is equipped with three ampmeters, six plug fuses, and six arc circuit plugs. The load on the entire system is balanced during the time that the

> arc lamps are in operation by plugging the unequal arc circuits on the phase necessary to give a balanced condition. [70]

Buchenberg concluded his description: "Although somewhat complicated, the wiring on the back of this switchboard is a model of compactness and accessibility, and the whole board represents the highest development in the art of this department of electrical construction" (see Figure 8). [71] The Wagner Electric Company manufactured all the switchboard instruments except the ground detectors. [72]

Martinsburg received the first electricity generated by the Dam 5 hydroelectric plant on November 1, 1904. [73] The 450 kilowatts generated by the Dam 5 plant permitted the electric company to solicit additional electric power customers and by 1905 newspapers, printers, quarries, some grain grinding mills, and the majority of Martinsburg's textile mills had installed electric motors to run their machinery. In assessing the impact of electricity upon Martinsburg, the Martinsburg Statesman concluded: "Tremendous as have been the changes brought about by the innovation of electric light, the adaptation of current for power purposes is fully as striking and significant." [74]

FOOTNOTES: CHAPTER II

[1] United Edison Manufacturing Co. to Mayor and City Council of Martinsburg, W.V., November 5, 1889, PEC Historical File: Edison United Manufacturing Co.

[2] Martinsburg Independent, November 23, 1889; PEC Historical File: Edison Electric Illuminating Company of Martinsburg, W.V.

[3] Martinsburg Independent, December 14, 1889; PEC Historical File: Edison Electric Illuminating Company of Martinsburg, W.V.

[4] Martinsburg Independent, December 14, 1889.

[5] Ibid.

[6] Deed Book 87, Berkeley County, W.V., March 29, 1890, pp. 208-210; "Abstract of the Property of the MPC Located in the City of Martinsburg, W.V.," pp. 1-2, 8-9, PEC; "Potomac Development Volume 1," pp. 23-28, PEC.

[7] Martinsburg World, August 31, 1892.

[8] Martinsburg Independent, January 4, February 1, February 16, March 1, 1890.

[9] Martinsburg Independent, March 29, April 5, 1890.

[10] Martinsburg Independent, April 12, 1890.

[11] Martinsburg Independent, April 19, 1890.

[12] Martinsburg Independent, April 26, 1890

[13] "Proposal and Specifications of the United Edison Manufacturing Company, NY, November 27, 1889," PEC Historical File: Edison United Manufacturing Company.

[14] Martinsburg Independent, April 12, 1890

[15] Ibid.

[16] Martinsburg Independent, April 26, 1890

[17] Martinsburg Independent, May 10, May 17, May 24, 1890.

[18] Martinsburg World, August 31, 1892; Independent, May 3, 1890.

[19] Deed Book 89, Berkeley County, W.V., November 24, 1891, p. 110; Records of Corporations, Berkeley County, W.V., March 19, 1891, p. 154; Martinsburg World, November 24, 1891, August 31, 1892.

[20] Martinsburg Independent, February 1, 1896; "Abstract of the Property of the MPC,", pp. 12-15, PEC

[21] Martinsburg Independent, January 26, February 2, February 9, 1895.

[22] Martinsburg Independent, February 2, 1895.

[23] Martinsburg Independent, January 26, 1895, February 1, April 18, 1896.

[24] Martinsburg Independent, February 1, 1896.

[25] Martinsburg Independent, April 5, 1890, January 26, June 29, 1895, April 18, 1896; The [Baltimore] Sun, January 11, 1901.

[26] Martinsburg Independent, February 1, 1896.

[27] Martinsburg Independent, April 11, 1896.

[28] Martinsburg Independent, March 23, 1895.

[29] "Abstract of the Property of the MPC," p. 12, PEC

[30] Martinsburg Independent, September 21, September 28, 1895; Deed Book 92, Berkeley County, W.V., September 26, 1895, p. 429.

[31] Ibid.

[32] Martinsburg Independent, November 2, November 30, December 21, 1895, January 18, 1896.

[33] Martinsburg Independent, February 8, April 18, 1896.

[34] "Abstract of the Property of the MPC," pp. 13-15, PEC; Martinsburg Independent, March 25, April 11, 1896; Certificate of Incorporation issued March 30, 1896, Deed Book, 95, Berkeley County, W.V., pp. 1, 3.; Records of Corporations, Book 1, Berkeley County, W.V., March 25, 1896, p. 242.; Deed Book 93, Berkeley County, W.V., March 31, 1896, p. 249, April 2, 1896, p. 258.

[35] Martinsburg Independent, April 18, May 16, 1896.; "Martinsburg Electric Light Company Minutes, April 1896-December 1900," p. 5, PEC.

[36] *Martinsburg Independent*, June 6, 1896.

[37] MELC Minutes, pp. 9-53.

[38] Ibid., p. 27.

[39] Ibid., pp 38-39.

[40] Ibid., p. 39.; *The National Cyclopaedia of American Biography*, Volume G - 1943-1946, p. 550 and Volume XXXV - 1949, pp. 78-79. NY: James T. White & Co., 1946.; *Potomac Edison News* 8 (December 1940): 2.

[41] MELC Minutes, January 29, 1897, p. 9.

[42] Ibid., pp. 5, 85.; Albert E. Walker, ed. *Martinsburg Statesman Industrial Edition* (Martinsburg, W.V.: Fairfax Publishing, July 1905), p. 21; *Martinsburg Herald*, June 21, 1902.

[43] MELC Minutes, pp. 80-91.

[44] *Martinsburg Statesman*, February 20, March 30, May 22, 1900.

[45] Ibid.

[47] Eleventh Census of the United States, 1890; Twelvth Census of the United States, 1900.

[46] *Martinsburg Statesman*, April 6, 1900.

[48] WVGS, *County Reports*, pp. 598-600.

[49] Opinion of Attorneys Johnson and Johnson, "Potomac Development Volume 1," PEC.

[50] *Martinsburg Herald*, June 20, June 21, 1902; PEC Historical File: MPC; Deed Book 84, Berkeley County, W.V., June 24, 1887, p. 346.

[51] *Martinsburg Statesman*, February 19, 1901.

[52] S.A. Williams to John P. Poe, July 2, 1901, "Potomac Development Volume 1," PEC.

[53] John P. Poe to S. A. Williams, July 3, 1901, "Potomac Development Volume 1," PEC.

[54] Ibid.

[55] *Martinsburg Herald*, February 8, 1902.

[56] Martinsburg Herald, February 8, February 21, June 20, June 21, June 28, 1902; Martinsburg Statesman, June 20, 1902, June 19, 1903.

[57] Martinsburg Statesman, June 20, 1902; Martinsburg Herald, June 20, June 21, 1902. [Deed ?]

[58] Deed Book 107, Berkeley County, W.V., April 15, 1903, p. 326, May 12, 1904, pp. 320, 326, 330; "Potomac Development Volume 1," pp. 21-23, PEC.

[59] Martinsburg Herald, February 24, February 27, 1904.

[60] A. E. Buchenberg, "A Recent High-Tension Installation," The Engineer, 42 (February 15, 1905): 129.

[61] Ibid.; Martinsburg Statesman, March 25, July 15, 1904.

[62] Buchenberg, "A Recent High Tension Installation," p. 129.

[63] Ibid.

[64] Ibid.; Lamar Lyndon, Development and Electrical Distribution of Water Power (New York: John Wiley, 1908), p. 63; Daniel W. Mead, Water Power Engineering (New York: McGraw Publishing, 1908), pp. 29-30.

[65] Francis H. Davies, "The Design of Rope Drives," Power and the Engineer 32 (August 16, 1910): 1461-1462; John J. Flather, Rope Driving (New York: John Wiley, 1897), 3-5; E.W. Kerr, Power and Power Transmission (New York: John Wiley, 1908), pp. 56-59; "Rope Driving in a Hydro-Electric Plant," Water Power Chronicle 2 (October 1913): 155; Walter B. Snow, "Limitation of Rope Drive," Power 34 (October 31, 1911): 657; Reginald Trautschold, "Transmission of Power by Manilla Rope," Power 39 (May 12, 1914): 666-667.

[66] Buchenberg, "A Recent High Tension Installation," pp. 169-130.

[67] Ibid., pp. 130-131.

[68] Ibid., p. 131.

[69] Ibid., p. 132.

[70] Ibid., pp. 131-132.

[71] Ibid., p. 132.

[72] Ibid.

[73] <u>Shepherdstown Register</u>, November 3, 1904.

[74] Walker, <u>Martinsburg Statesman Industrial Edition</u>, p. 21; <u>Martinsburg Herald</u>, August 5, 1905.

CHAPTER III

THE DAM 4 HYDROELECTRIC PLANT

EXPANDING MARKETS

Less than two years after completing the Dam 5 plant, population growth in the City of Martinsburg and across Berkeley and Jefferson counties, the prospects of supplying electricity to a proposed regional trolley system, and the gradual emergence of competition from newly incorporated and expanding electric companies in both West Virginia and Virginia prompted the management of the Martinsburg Power Company to once again reevaluate the adequacy of the company's existing generating capacity. Between 1900 and 1905, the textile industry, the foundation of Martinsburg's dynamic economic growth during the 1890s, continued to expand rapidly; for example, the Shenandoah Pants Company, established in 1895, constructed a major new mill in 1901 and the Crawford Woolen Company mill expanded almost three fold, from 9,900 square feet in 1891 to 27,500 square feet by 1905. [1]

Limestone, used as flux in the open hearth steel making process and in the making of glass, fertilizer, and building lime, also contributed to the region's healthy economic growth. The Standard Lime and Stone Company, with quarries on the south and west side of Martinsburg, and the Blair quarries east of the city, both extracted as much as 4,000 tons of stone per day. Eight miles east of the city, in Kearneysville, limestone quarries also became a major employer by 1905. [2] Martinsburg's distilleries, foundries, and small manufacturers, while overshadowed by the textile mills and quarries, also displayed strong growth in the years after 1900. Rent and housing price increases and a scarcity of housing between 1903 and 1905 reflected the area's robust economic and population growth. The Martinsburg Statesman, for example, lamented that despite "a great deal of building" not "an empty house" was available to accomodate the many new arrivals seeking employment in Martinsburg's mills, factories, and quarries. [3] By 1905, the Martinsburg Power Company illuminated 7,000 incandescent and 60 arc lights. [4]

Responding to the growth of the region, a group of Washington, D. C. and Baltimore businessmen, led by Martinsburg Power Company's Vice-President S. A. Williams, sought to construct an electric railway linking Hagerstown, Williamsport, and Antietam, Maryland; Shepherdstown, Charles Town, and Martinsburg, West Virginia; and Winchester and Berryville, Virginia. The Shepherdstown Register reported that Williams had raised $150,000 to purchase the abandoned dam and pulp mill at Harpers Ferry and was apparently planning to convert the mill into a hydroelectric plant that would generate electricity for the bulk of the proposed railway. [5] Independent of Williams activities, a group of Martinsburg entrepreneurs, represented by Stuart Walker and James Thompson, applied for a franchise to construct and operate an electric street car line within the limits of the City of Martinsburg. [6] Electricity for both the proposed Martinsburg street car line and the Williamsport and Martinsburg portions of William's proposed electric railway system was to be supplied by the Martinsburg Power Company. [7]

The incorporation of electric light and power companies in neighboring communities revealed the growing market for electricity that existed outside of Martinsburg in the small but constantly growing towns and cities scattered along the Potomac and Shenandoah River valleys. At the western end of Berkeley County, the Cacapon Power Company was formed in 1904 to supply electricity to the town of Berkeley Springs and the area's growing number of quarries extracting the high quality sand used by West Virginia's glass industry. [8] To the east, in Virginia, the Winchester and Washington City Railway Company was also incorporated in 1904 with the objective of constructing an electric railway linking the Virginia cities of Winchester and Alexandria, a suburb of the District of Columbia, and generating and distributing electricity in Winchester and Berryville, Virginia and Charles Town, West Virginia. [9] George A. Rumsey of the Rumsey Electric Manufacturing Company sold to the Winchester and Washington City Railway his rights to develop the defunct Millville Water Power Company dam site on the Shenandoah River and, by August 1905, a contract for a new dam and raceway at the site had been signed. [10] The Winchester and Washington City's Board of Directors accepted the proposal of B. F. Groff, a Lancaster, Pennsylvania civil engineer and sales representative of the James Leffel and Company of Springfield, Ohio, to eguip the Millville hydroelectric plant with two 45 inch diameter horizontal shaft turbines. Westinghouse Electric was chosen to supply two rope driven, 500 kilowatt, 360 rpm horizontal shaft alternating current generators, each with a Lombard "Type O" governor. [11]

EXPANDING POTOMAC RIVER HYDROELECTRIC GENERATION

Groff also approached Martinsburg Power in 1905 with a plan for replacing the three vertical turbines at the Dam 5 hydroelectric plant with two 56 inch diameter Leffel vertical shaft turbines. Each "Upright Samson" turbine that Groff proposed installing at Dam 5 rotated at 116 revolutions per minute under a 16 foot head and produced 405 horsepower with the wicket gates fully opened, discharging 16,554 cubic feet of water per minute through a 75 inch diameter steel draft tube. Groff guaranteed that after deducting for friction loss in the shafting and rope drive, the two turbines would deliver a total of 700 actual horsepower to the shaft of the electric generator at the Dam 5 plant. [12] After studying Groff's proposal for replacing the hydraulic equipment at the Dam 5 plant, and, no doubt, examining the local economy, the opportunities for expanding markets, and, perhaps, the nascent threat of competition for the territory beyond the immediate vicinity of Martinsburg, the management of the Martinsburg Power Company decided not only to upgrade the Dam 5 plant, but also construct a second, much larger hydroelectric station on the West Virginia side of the Potomac at the Chesapeake and Ohio Canal Company's Dam 4.

Having successfully used Chesapeake and Ohio Canal Dam 5, the decision to develop Dam 4 was a logical attempt to minimize costs and expedite the construction and operation of a plant designed to serve Martinsburg, the eastern part of Berkeley County, and the western half of Jefferson County, including Shepherdstown and the limestone quarries at Kearneysville. [13]

After obtaining a franchise to erect a transmission line from Dam 4 to Shepherdstown and Martinsburg, with a separate branch line to the Kearneysville quarries, the Martinsburg Power Company purchased, from four different owners, 18.2 acres of land adjoining the West Virginia abutment of Dam 4. The total cost of the land and access between the dam and the public road at Scrabble (see HAER drawing WV-27-2) was $3,000. [14] Purchasing access to the site was required because no mill had ever been built at Dam 4.

PLANNING THE DAM 4 HYDROELECTRIC PLANT

Constraints arising during the negotiations between Martinsburg Power and the Chesapeake and Ohio Canal Company established the structural configuration and placed limits on the potential output of the proposed plant. A contract between the Canal Company and Martinsburg Power, signed in 1906, stipulated:

> The Power Company shall have the right to draw water...only at such times as such drawing may not interfere with the operation and navigation of said canal. At Dam 4, the Power Company shall have the right to take water when the water is flowing over the crest of the dam. [15]

To assure that Martinsburg Power used only "surplus water," the contract further specified:

> If the Power Company fails to shut off the water at

> either of its plants when it should do so under this agreement, then such person or persons, as may be authorized by the [Chesapeake and Ohio Canal Company] General Manager, shall have the right to enter upon the premises of the Power Company for that purpose. [16]

Additionally, all construction plans prepared by the electric company had to be submitted to and approved by the Canal Company's General Manager before construction could begin. The cost of the water at Dams 4 and 5 was five percent of the electric company's net earnings with mandatory minimum fees of $500 per year at Dam 4 and $400 per year at Dam 5. [17]

The use of only unspecified amounts of "surplus water," the widely fluctuating needs of the canal, the highly variable natural flow of the Potomac River, and the lack of accurate stream flow and flow duration records complicated the selection of the theoretically most efficient sized turbine. In addition, the inability to store water behind the dam prevented any regulation of the Potomac's flow and, consequently, precluded the use of the proposed Dam 4 hydroelectric plant as a constant output, base load generating station.

If determining the size of the most efficient turbine was an almost impossible task, determining the type, arrangement, and configuration of the turbines was far less difficult. Hydraulic textbooks and much practical experience specified the use of dual runner, horizontal shaft turbines at low head plants such as the one proposed for Dam 4. Vertical shaft turbines, such as those used at the Dam 5 plant, operated more efficiently, however, friction generated by the gears and shafts used to transmit mechanical power from the turbine to the generator seriously reduced the actual horsepower reaching the generator. Because they could be connected to efficient, high speed horizontal shaft generators without using gears and shafts, horizontal shaft turbines, especially dual runner models, had become popular, if not standard, low head equipment by 1906. [18] Civil and hydraulic engineer H. A. von Schon, writing in the 1908 edition of his textbook, Hydro-Electric Practice, asserted that the submerged, multi-runner horizontal shaft turbine was "best adapted to low and medium heads and...is of the highest practical efficiency." [19] As late as 1914, civil engineer H. Birchard Taylor, addressing the Canadian Society of Civil Engineers, declared: "Until the last two years, a very large majority of the turbines installed in connection with low and medium heads were of the old fashioned [horizontal shaft], multi-runner type." He described how a single horizontal shaft fitted with "two, four, six, and sometimes more runners grouped in pairs, each pair discharging into a common draft chest and tube," produced the "high rotational speeds" required by the most efficient and economical generators. [20]

Martinsburg Power Company Chief Engineer H. B. Shoemaker, seeking a low cost and highly reliable plant, did not deviate from the prevailing and proven designs when he prepared the hydraulic specifications for the Dam 4 hydroelectric plant. Shoemaker's original design called for the construction of a building capable of accomodating three sets of turbine-generator units. [21] His actual construction specifications, however, required the installation of only two turbine-generator units; most likely because of the fear of insufficient water and the desire to meet immediate demand at minimum cost while allowing for future expansion.

Shoemaker's hydraulic specifications required the installation of two sets of tandem horizontal shaft, dual runner, center discharge turbines. Each tandem turbine set was required to generate "not less than 750 horsepower under a 15 foot effective head" and have a minimum speed of 150 revolutions per minute. Shoemaker demanded that the turbines operate at "80 percent or better efficiency at three-fourths to full gate opening." [22]

Avoiding flood damage to the generators, exciters, and switchboard necessitated elevating the electrical apparatus, as was done at the Dam 5 plant, as high above the Potomac River as economically possible. Having chosen horizontal shaft turbines, Shoemaker sought not only to connect these units to horizontal shaft generators rotating at 360 rpm, but also to minimize the loss of horsepower in the transmission of mechanical power from the turbines to the generators. Thus he decided, as he had when building the plant at Dam 5, that rope drive was the logical and most efficient mechanism.

CONSTRUCTION OF THE PLANT AT DAM 4

Two firms, the S. Morgan Smith Company of York, Pennsylvania and James Leffel and Company, Springfield, Ohio, responded to the invitation to bid on the Dam 4 plant hydraulic system contract. [23] The Rumsey Electric Manufacturing Company (which had supplied and installed the Warren Electric generators at both the Martinsburg steam and Dam 5 hydroelectric plants) and the General Electric Company submitted bids for the electrical equipment contract. [24] Morgan Smith proposed installing 39 inch diameter horizontal turbines. B. F. Groff, the Leffel representative, promised that his company's 40 inch diameter horizontal Francis turbines would operate at a higher speed, deliver five percent more horsepower, and use a smaller, lighter drive pulley for the rope drive system. The competition for a contract worth between 30,000 and 40,000 dollars produced fiercely competitive, exceptionally low bids. Groff's bid of $33,000 was 1,666 dollars below the Morgan-Smith Company bid of $34,666. The Leffel equipment, in addition to being slightly less expensive, was also heavier, weighing 12,000 pounds more than the Morgan-Smith equipment. [25] If the lower price, heavier weight, higher speed, and larger horsepower did not clinch the contract for the Leffel Company, Groff's offer to purchase $10,000 worth of Martinsburg Power Company second mortgage bonds if he won the contract, [26] most certainly assured his company being awarded the hydraulic contract. In the competition to supply electrical equipment, the Rumsey brother's previous work for the Martinsburg Power Company and its predecessor, Martinsburg Electric Light Company, and the brother's willingness to purchase $20,000 worth of Martinsburg Power mortgage bonds, [27] guaranteed their success in the bidding against General Electric.

By June 1906, all the contracts, except the one for the construction of the transmission line between Dam 4 and Martinsburg, had been awarded. Chief Engineer Shoemaker estimated that the cost of constructing and equiping the Dam 4 plant would total $135,000. An additional $7,000 was to be spent to acquire the two Leffel turbines and new line shaft and rope drive system for the Dam 5 plant. [28] Two groups of Italian workmen, the first contingent of a work force that grew to 75 men, arrived the following month. [29] Excavation and site preparation required a large quantity of explosives and one ton of dynamite was included in the first shipment of supplies. A towering limestone cliff, nearly 100 feet high, was blasted away from the West Virginia shoreline to permit construction of the headgates and excavation of the forebay and power house foundation. [30] Ribs of rocky limestone, protruding into the river just below the dam, were likewise blasted and excavated to form the plant's tailrace. Limestone obtained from the blasting and excavation was cut, dressed, and used to construct the plant itself, from the foundation up. [31] (Photograph HAER WV-27-8 illustrates the site during excavation.)

In August, only two months after construction had begun, the workmen, demanding a wage of $1.75 per day, went on strike. [32] One month later, a fire consumed the construction camp's bunk houses and incinerated all of the workmen's personal possessions and accumulated pay. [33] Other labor troubles erupted when laborers who had been recruited in Harrisburg, Pennsylvania became disenchanted with the conditions of their employment and abandoned the job after less than a day of work. [34] The longest and most serious disruption came during the spring and summer of 1908. With the building less than half completed and requiring at least another six months of work, the construction contractor, Shoaf and Brubaker of Lancaster, Pennsylvania, abandoned the project. [35] Experienced in commercial and highway construction only, Shoaf and Brubaker had never before attempted to construct a hydroelectric plant or, apparently, work at a site subject to frequent flooding. On two occasions, once in 1907 and again in 1908, floods disrupted construction and swept building materials downstream. The loss of material and the unanticipated delays in construction inflicted heavy financial losses upon the two contractors and ultimately prompted them to abandon the project in March of 1908. They left the plant less than one-half complete with both the forebay and tailrace only partially excavated. [36]

During June, contractors visited Dam 4 and prepared estimates of the cost of completing the half-finished plant. [37] Work finally resumed in late July under the direction of a Baltimore construction firm, Kefauver and Shreve. [38] In a report to the management of the Martinsburg Power Company, hydraulic engineer Groff estimated that the plant would be generating electricity by December. [39] Kefauver and Shreve, however, fared little better than their predecessor in attempting to complete the Dam 4 plant without difficulty and delay, and not until March of 1909 did the building approach completion. In February 1909, while working on Sunday to expedite the completion of the project, a scaffold collapsed and a small group of masons, along with several tons of stone and lumber, fell some 15 feet into the river. Fortunately, all the workers escaped death, although one workman did suffer serious injuries. [40] Floods during April and May once again swept away building materials and disrupted construction. The May 1909 flood at one point threatened to overwhelm the cofferdam protecting the forebay construction and workmen spent two days pumping water out of the forebay and the power house before resuming construction activities on the almost completed building. [41] By July 1909, as the generating equipment began arriving at the Shepherdstown railroad station, workmen had installed the timber roof trusses and needed only to cover the roof with slate shingles to complete the building (as shown in photograph HAER WV-27-11). [42] Hauling the thousands of pounds of hydraulic and electrical equipment, including two 15 ton electric generators and three five ton transformers, between Shepherdstown and Dam 4 proved a most difficult, arduous, and time consuming task despite the use of two steam traction engines. With a steam tractor at each end of the wagon bearing one of the two 15 ton electric generators, local teamsters spent four full days transporting the large machine five miles between the Shepherdstown rail depot and Dam 4. [43]

THE OPERATION OF THE DAM 4 HYDROELECTRIC PLANT

Because the Chesapeake and Ohio Canal Company permitted the plant to take only water not needed by the canal, the diversion of water into the plant at Dam 4 was carefully regulated and controlled. Water flowed through twelve 5 foot wide by 12 foot high fully submerged timber inlet gates and into an 80 by 200 foot open forebay that had been blasted out of the limestone cliff where the West Virginia abutment of Dam 4 was previously anchored (see HAER drawing WV-27-1). To regulate the water flowing into the forebay, these twelve gates could be raised and lowered using manually operated worm gear hoists (see HAER photos WV-27-20 and 21). In addition to regulating the water, the submerged inlet gates also effectively restricted the flow of ice into the forebay. Excess water in the forebay was easily discharged back into the river through two small sluice gates, also manually operated by worm gear hoists.

Immediately before reaching the turbine pits at the downstream end of the forebay, vertical steel grate trash racks strained the water of ice and large debris. Wooden headgates, constructed of two inch thick plank boards and reinforced with twelve inch square wooden girders, separated the forebay from the 21 foot wide, 12 foot deep turbine pits (sometimes called open penstocks) and controlled the flow of water (see HAER drawing WV-27-5). The wide forebay and open penstocks maximized water velocity and minimized penstock friction losses.

The plant was constructed with three turbine pits, but only the two pits adjacent to the river were fitted with hydraulic machinery. Once in the turbine pit, the water descended through a linked pair of Leffel Type 22 "Sansom," (Leffel's trade name for a Francis) 40 inch diameter, dual runner, center discharge, horizontal shaft turbines and exited through a tapered steel draft tube. Each of the four dual runner turbines was equipped with a draft tube and, after falling 17 feet and 4 inches, the water flowed beneath the building and into an approximately 500 foot long, 90 foot wide rock-lined tailrace channel before finally flowing back into the Potomac River (see HAER drawings WV-27-4 and 5, and HAER photos WV-27-13, 26, and 29).

Mechanical power developed by the fall of the water (the head) caused each tandem pair of turbines to rotate at 168 revolutions per minute and generate 850 horsepower while discharging 32,460 cubic feet of water per minute (541 cfs). The structural system supporting the turbines and turbine pit floor consisted of twelve inch square timber beams and twenty inch deep, 65 pound per linear foot steel I-beams, both anchored into the stone side walls. Eight inch diameter cast iron columns reinforced the steel beams at midspan. The turbine pit floor was constructed of three inch thick white pine planking. [44]

The heavy underpinning of the turbine pit floor was dictated not only by the weight of the turbines and water, but also by the special characteristics of single shaft, tandem horizontal turbines. The Leffel Company specified:

> It is highly essential in tandem work that the entire underpinning or foundation and floor work should be very firm and solid so that the weight of the wheels, shafts, casing, and water may not spring them [the turbine shafts] out of line or level. Serious wear and other damages will result if proper care is not exercised when installing the wheel work. [45]

Outside of the casing, the turbine shaft rested on submerged "lignum vitae" wooden bearing blocks carried by cast iron pedestals bolted into the wooden beams that supported the turbine pit floor. Inside the center of each turbine casing, a removable center bridgetree housed another submerged "lignum vitae" bearing. This bearing supported the portion of the shaft connecting the dual runners. To facilitate repairs, the turbine casing was split and bolted together along a vertical plane parallel to the turbine shaft. (HAER photo WV-27-28 shows the turbine casing and attached wicket gates.)

Wicket gates kept the turbine running at a constant 168 rpm by regulating the volume of water flowing into the runners. A cast iron rod connected the wicket gates to a two inch diameter horizontal gate shaft which, after entering the basement of the plant, was attached by a pulley and wire to a Lombard speed regulating governor.

A four foot square, four foot deep cast iron "stuffing box" permitted the turbine shaft to pass through the four foot thick stone and concrete bulkhead separating the open turbine pit from the lower sheave wheel pit inside the basement of the plant. Each stuffing box contained a set of babbited, cast iron bearings and split brass oiling rings. Identical, but smaller, stuffing boxes allowed the wicket gate control shaft to penetrate the bulkhead and enter the plant's basement.

Inside the lower sheave wheel pit, the extended turbine shaft was connected to a ten foot diameter sheave wheel. Two 1,250 foot long, one and one-half inch diameter "Furmis" sisal ropes, imported from Brazil, were used to transmit power from the lower sheave wheel 36 feet 10 inches to the upper sheave wheel located on the generator floor directly above. Both wheels were of similar steel construction and carried two sets of 13 V shaped grooves--one set of grooves for each rope--with each groove being one and five-eighths inches wide. The upper sheave wheel, however, was four feet five inches in diameter and, due to its smaller size, rotated at 360 rpm to the lower wheel's 168 rpm (see HAER drawings 5 and 6). [46]

Each rope was wound alternately over the upper sheave wheel and under the lower one; after its thirteenth loop, each rope was returned to its first groove via a 52 inch diameter tension carriage sheave. The tension carriages rode vertically between sets of steel I-beams and took up the rope slack that resulted from wear, stretching, and from expansion due to summer heat. The carriages also kept the ropes under constant tension in order to prevent them from slipping on the sheave wheels. In more recent years it was found that one rope was sufficient to run each generator, so one set of grooves on each sheave wheel now goes unused, along with the attendant tension carriage (see HAER photo WV-27-40). Each rope travels at 5,000 feet per minute and safely transmits a maximum of 900 horsepower. [47] Figure 9 depicts the transmission of mechanical power between the turbines and the generators.

Each upper sheave wheel was connected by a 14 foot long horizontal steel shaft to a 360 rpm revolving field electric generator. Each of these two 20 pole, three-phase, 60 cycle, Y connected, alternating current generators produced 500 kilowatts and a maximum of 2,500 volts. The Warren Electric Manufacturing Company of Sandusky, Ohio manufactured both of the original two generators installed in the Dam 4 plant. [48] In 1909, for unspecified reasons, the electrical contractor, the Rumsey Electrical Manufacturing Company, substituted a 500 kilowatt, (625 kVa at a power factor of .8) 2,500 maximum volt alternating current generator manufactured by the Electric Machinery Company of Minneapolis, Minnesota for one of the three Warren Electric generators originally purchased in 1907. The Electric Machinery Company generator, like its Warren Electric predecessor, operated at 360 rpm and produced three-phase, 60 cycle alternating current. Unlike the original Warren generators, the new generator was "chain wound." The rated efficiency of the Electric Machinery generator at a 100 percent power factor was: [49]

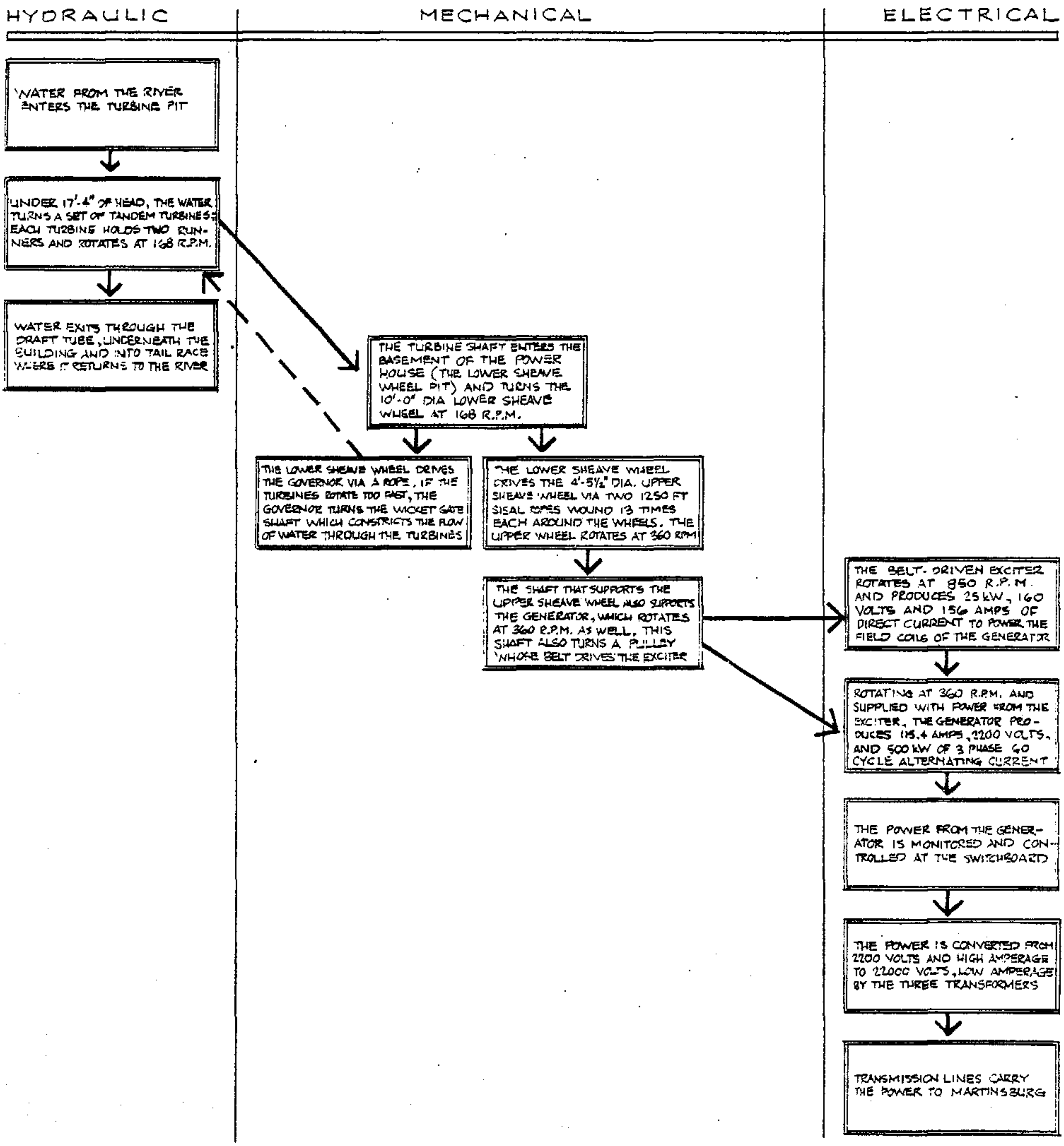
Load	Full	75%	50%	25%
Efficiency	95%	93.5%	88%	86%

The Warren generator, serial number 698, on the north side of the building, was designated unit 1 and the Electric Machinery generator, serial number 351973, on the south side of the plant, was designated unit 2. (HAER photos WV-27-36 and 38 illustrate the two generators.)

To prevent the generators from rotating at speeds in excess of 360 rpm, two Lombard Type O horizontal governors maintained the speed of the turbines at 168 rpm by adjusting the wicket gate openings in response to any changes in load or head. The Type O governor, using a seven and one-half inch diameter piston with a 24 inch stroke, exerted a maximum 16,000 foot-pounds of pressure on the wicket gate ring, but because it was the slowest Lombard governor, required four seconds to fully open or close the wicket

FIGURE 9

THE GENERATION OF ELECTRICAL POWER FROM FALLING WATER AT DAM NUMBER 4



gates (see HAER photo WV-27-37). [50]

In order for each of the generators to produce alternating current, rotating electromagnets, known as field coils, had to be supplied with direct current. The Warren Electric unit, with twenty field coils or poles, and the Electric Machinery units, with twenty-four field coils, each had an exciter (a small direct-current generator) driven by a belt attached to the generator shaft. Although the exciter linked to the Warren generator was built by Warren Electric and the exciter attached to the Electric Machinery Company generator was built by that company, both of these multipole exciters rotated at 850 rpm to produce twenty-five kilowatts, 160 volts, and 156 amperes of direct current. [51] A manually operated 20 ton Niles overhead traveling crane was used to install and remove the plant's heavy machinery.

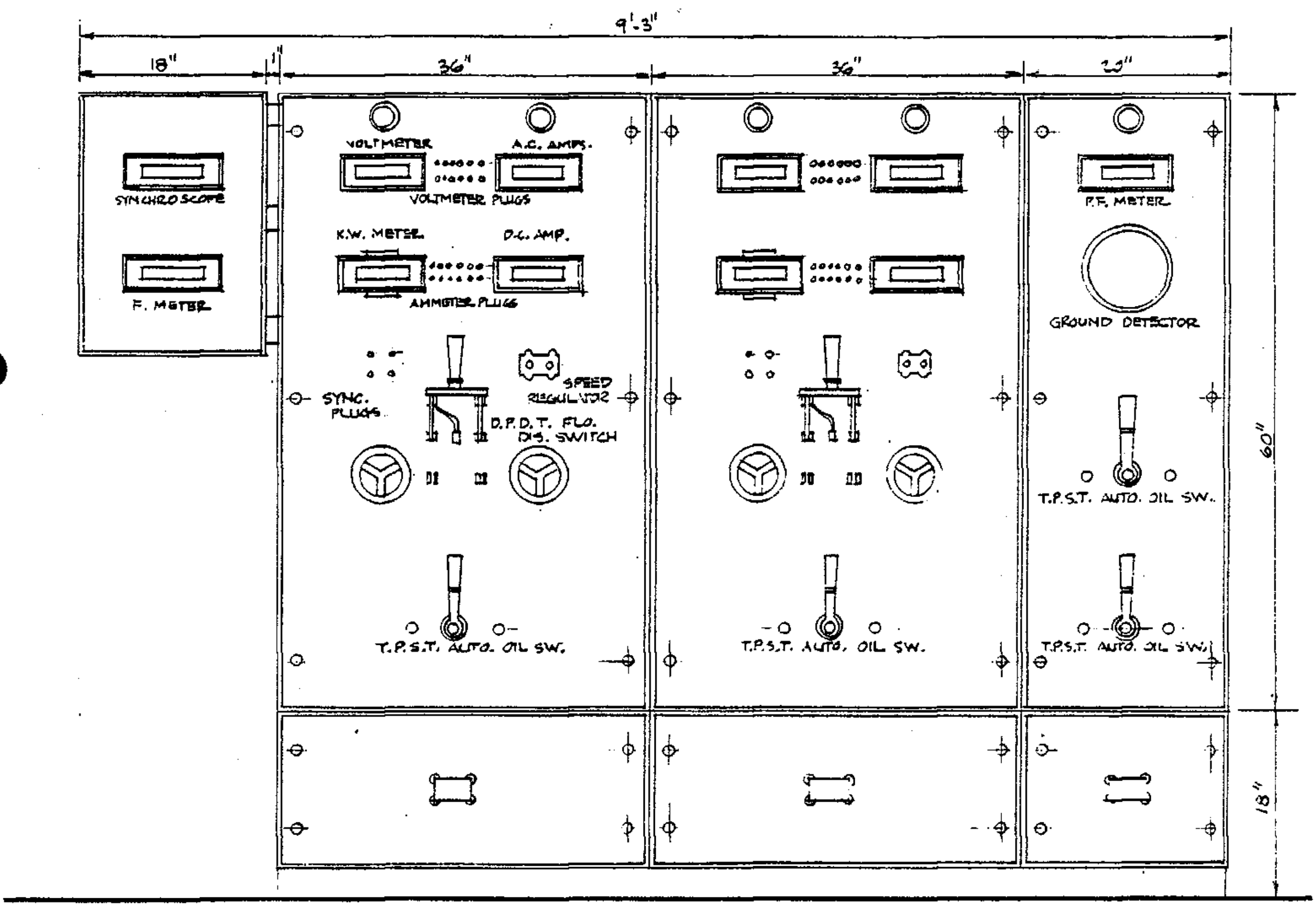
The switchboard at the Dam 4 plant was designed to operate the two 500 kilowatt generators either singly or in parallel and was configured to accommodate the eventual installation of a third generator. Each generator was monitored and controlled by a separate seven and one-half foot high by 36 inch wide panel containing:

1 voltmeter, 150 volt maximum reading
1 ampere meter, 200 amp maximum reading
1 kilowatt meter, 750 kW maximum reading
1 frequency indicator
1 triple pole single throw (TPST) automatic oil switch

Each of the two panels also included a direct current ampmeter and a double pole double throw (DPDT) field discharge switch needed to monitor and control the direct current exciters. A separate panel housed a triple pole single throw 1,500 kilowatt automatic switch for the control of all current fed to the transformers; a triple pole single throw automatic switch for the independent lighting circuit; a static, three-phase, 2,200 volt ground detector connected to the cable leading to the high-tension transformers; and a power factor meter. A smaller panel contained the synchroscope, synchronizing plugs, and a frequency meter. Figure 10 illustrates the front of the switchboard. A single 2,200 to 110 volt, 10 kilowatt transformer, attached to the rear of the switchboard supplied current to the plant's exterior arc and interior incandescent lights. The switchboard, although manufactured by the Warren Electric Company and installed by the Rumsey Electric Company, used Wagner instruments, Condit and Hartman switches, and Westinghouse Electric fuses. The Westinghouse Company also supplied the choke coils, the static dischargers, and the three-phase, 2,200 volt lightning arresters installed at the Dam 4 plant. [52] (The original switchboard is seen on the left side of HAER photos WV-27-33 and 35.)

FIGURE 10

SWITCHBOARD, DAM 4 PLANT (1909)



THIS SWITCHBOARD IS COPIED FROM DRAWING 62942 OF THE WARREN ELECTRIC MFG. CO., SANDUSKY, OHIO. (N.D.)

After leaving the switchboard, a single set of feeder cables carried the electricity out of the plant to a trio of 500 kilowatt transformers set upon the hill behind the plant. These oil insulated, air cooled transformers, manufactured by the Pittsburgh Electric Company, raised the current from 2,200 to 22,000 volts for transmission on a single circuit to Martinsburg. Transformer efficiency was rated at:

Load	Full	75%	50%	25%
Efficiency at 500 kilowatts	98.5%	98.4%	97.5%	95%

At the Martinsburg generating station, transformers reduced the current to 2,200 volts for distribution to local customers. To monitor and control the distribution of the electricity generated by the Dam 4 hydroelectric plant, an additional panel was added to the switchboard inside the Martinsburg generating station. The new panel included kilowatt, volt, and ampere meters and a three-phase triple-pole double-throw automatic switch. [53] Current generated by the Dam 4 plant was transmitted to Martinsburg by a 16 mile long, 22,000 volt high tension line routed through Shepherdstown. [54] No direct connection between the two hydroelectric plants existed.

Placed into operation on October 23, 1909, the Dam 4 plant cost approximately $223,000. [55] The final cost, more than $87,000 above the original 1906 estimate, reflected the numerous delays and difficulties encountered during three years of construction. To finance the construction of the Dam 4 plant and improvements made at the Dam 5 and Martinsburg plants, the electric company issued $500,000 worth of second mortgage bonds paying 5 percent interest semi-annually and redeemable after 20 years. [56]

Fortunately, the Martinsburg Power Company had not chosen to rely exclusively upon the completion of the Dam 4 plant to meet the growing demand of the company's customers. During 1907 the electric company significantly expanded the Martinsburg steam generating plant by adding a large brick building with a 215 foot tall smokestack. The addition housed two new steam boilers and a 1,000 horsepower Atlas heavy duty Corliss engine equipped with 28 by 48 inch high pressure cylinders. Attached to the engine shaft was an 18 foot diameter rope drive sheave wheel with 26 one and one-half inch grooves. The sheave wheel, rotating at 85 rpm, was connected by a horizontal rope drive system to a 360 rpm, 500 kilowatt Warren Electric alternating current generator also purchased in 1907 (see photos HAER WV-27-2, 5, 6, and 7) [57]. Although the generating capacity of the Dam 5 plant was not expanded, engineer Shoemaker replaced the plant's three original 66 inch diameter turbines with two 56 inch diameter vertical shaft Leffel turbines. [58]

With the completion of the Dam 4 plant, the Martinsburg Power Company operated three electric generating stations. At Dam 4, the company maintained 1,000 kilowatts of generating capacity while the Dam 5 plant produced 450 kilowatts. The steam engines housed in the Martinsburg generating station produced 1,400 horsepower and powered electric generators producing 900 kilowatts of alternating current. Of the total 2,350 kilowatts generated by the Martinsburg Power Company, an estimated 1,300 kilowatts was consumed by incandescent lighting and approximately 820 kilowatts was used by electric motors operated by industrial customers. The electric company also supplied electricity for 75 incandescent and 85 arc street lights in the City of Martinsburg, and distributed electricity generated by the Dam 4 plant to a portion of Shepherdstown in Jefferson County. Additional income was obtained from the sale of a "complete line" of electric supplies and electrical appliances, including electric stoves and heaters, at the electric company's Martinsburg office. [59]

FOOTNOTES: CHAPTER III

[1] Walker, Martinsburg Statesman Industrial Edition, p. 18; Martinsburg Statesman, June 30, 1905.

[2] Martinsburg Statesman, March 11, 1904; Berkeley County limestone quarries are described in WVGS, County Reports, pp. 396-416.

[3] Martinsburg Statesman, January 23, 1903, April 8, 1904, March 31, 1905.

[4] Walker, Martinsburg Statesman Industrial Edition, p. 21.

[5] Shepherdstown Register, February 9, 1905.

[6] Shepherdstown Register, March 15, 1906; Electrical World 67 (June 16, 1906):1277; Electrical World 67 (March 24, 1906):641; Martinsburg Herald, March 17, 1906.

[7] Martinsburg Statesman, June 8, 1906; Martinsburg Herald, March 17, 1906; Shepherdstown Register, February 9, 1905.

[8] Information on the Berkeley County glass sand industry and a description of the quarries appears in WVGS, County Reports, pp. , 332-341 and WVGS, Volume VI, pp. 378-390.

[9] Shepherdstown Register, June 22, 1905; Martinsburg Statesman Democrat, November 23, 1906; WVPSC, First Annual Report, p. 440; PEC Historical File: W&WCRC.

[10] Shepherdstown Register, June 15, June 22, 1905; PEC Historical File: W&WCRC, May 11, May 19, August 2, 1905; "Structures and Generating Station Equipment," p. 119, PEC.

[11] Shepherdstown Register, October 26, October 27, November 9, 1905; PEC Historical File: W&WCRC, October 18, November 2, 1905; PEC to Leffel, August 27, 1937, Leffel File PP-464.

[12] Drawing 1232 and "Specifications for the Remodeling of the Water Power Plant at Dam 5," PEC Minor Stations.

[13] Electrical World (February 24, 1906):430; Shepherdstown Register, February 8, 1906; Martinsburg Statesman, February 16, 1906.

[14] Shepherdstown Register, March 8, 1906; Deed, John Russell et al and MPC, July 24, 1907, Deed Book 117, p. 153.; Deed, Raleigh and Emma Williams and MPC, June 23, 1906, Deed Book 97, p.

490.; Deed, John and Mary Walker and MPC, May 29, 1906, Deed Book 111, p. 376.; Deed, Estate of Susan McGraw and MPC, July 24, 1907, Deed Book 117, p. 153. All deeds cited in Tract 1, "Potomac Development Volume 1," and the "Legal Notice: Public Sale of the Property of the MPC," MPC Scrapbook, PEC.

[15] Agreement MPC and C&O dated, June 1, 1906, "Potomac Development Volume 1," PEC.

[16] Ibid.

[17] Ibid.; Shepherdstown Register, September 6, 1906; Martinsburg Herald, September 1, 1906; W.B. Shoemaker to G.L. Nicolson, August 17, 1908, October 1, 1909, September 24, 1910, C&O Papers, NA.; "Report and Petition," C&O Equity Cases 4191 and 4198, Washington County Court, Hagerstown, Md.

[18] William P. Creager, Hydro-Electric Handbook (New York: John Wiley, 1927), pp. 577-578; Lamar Lyndon, Development and Electrical Distribution of Water Power (New York: John Wiley, 1908), pp. 62-63; Daniel W. Mead, Water Power Engineering (New York: McGraw Publishing, 1908), pp. 513, 529; David B. Rushmore and Eric A. Lof, Hydro-Electric Power Stations (New York: John Wiley, 1917), pp. 227, 325; H.A. von Schon, Hydro-Electric Practice (Philadelphia: J.B. Lippincott, 1908), pp. 260, 301.

[19] von Schon, Hydro-Electric Practice, p. 308.

[20] H. Birchard Taylor, "Hydraulic Turbines," Water Power Chronicle 3 (June 1914):269-271; H. Birchard Taylor, "Present Practice in the Design and Construction of Hydraulic Turbines," Proceedings of the Canadian Society of Civil Engineers (Montreal, Canada, 1914):133, 137.

[21] "Specifications: MPC Turbine Equipment," PEC Minor Stations.

[22] Ibid.

[23] Rumsey Electrical Manufacturing Co. to S.A. Williams, April 25, 1906, Dam 4 File, PEC Minor Stations.

[24] Ibid.

[25] Ibid.; Rumsey Electrical Manufacturing Co. to F.E. Wilson, April 27, 1906, Dam 4 File, PEC Minor Stations.

[26] Rumsey to Williams, April 25, 1906, Dam 4 File, PEC Minor Stations.

[27] Ibid.

[28] Ibid.; Electrical World, 67 (June 16, 1906):1277; Southern Electrician, (July 1906):22; Martinsburg Statesman, June 8, 1906; Martinsburg Statesman Democrat, June 28, 1906; Shepherdstown Register, June 14, June 22, 1906; Martinsburg Herald, June 9. 1906; "Specifications: MPC Turbine Equipment," PEC Minor Stations.

[29] Martinsburg Statesman, July 6, 1906, July 27, 1906; Martinsburg Herald, September 1, 1906; Shepherdstown Register, July 12, 1906.

[30] Martinsburg Statesman, July 6, July 27, 1906.

[31] Martinsburg Statesman Democrat, September 17, October 29, 1909; "Specifications: Dams 4 and 5, Power House," PEC Minor Stations.

[32] Martinsburg Statesman, August 17, 1906.

[33] Martinsburg Statesman Democrat, September 21, 1906.

[34] Martinsburg Herald, October 27, 1906.

[35] Martinsburg Statesman Democrat, June 6, 1908.

[36] Ibid.; Shepherdstown Register, September 17, 1908; Potomac Edison News, 18 (December 1940):2.

[37] Martinsburg Statesman Democrat, July 4, 1908; Shepherdstown Register, June 25, 1908.

[38] Martinsburg Statesman Democrat, July 2, 1909; Shepherdstown Register July 16, July 23, 1908.

[39] Electrical World (August 7, 1908):273.

[40] Shepherdstown Register, February 18, 1909.

[41] Shepherdstown Register, April 23, 1909, May 27, 1909.

[42] Martinsburg Statesman Democrat, July 2, 1909.

[43] Shepherdstown Register, October 7, October 14, 1909.

[44] "Specifications: Dams 4 and 5, Power House," PEC Minor Stations; "Specifications: MPC Turbine Equipment," PEC Minor Stations.

[45] "Leffel Samson and Niagara Turbine Water Wheels," James Leffel and Co., 1908, p. 21, National Museum of American History, Washington, D.C.

[46] Drawing 556 and "Specifications: MPC Turbine Equipment," PEC Minor Stations.

[47] Interview with Tony Robucci, Superintendent of Minor Stations, Potomac Edison Company, Hagerstown, Maryland, August 1980.

[48] Drawing 62940 and "Electrical Specifications, Dam 4," PEC Minor Stations.

[49] Ibid.; "Proposal for Electric Machinery Manufactured by the Electric Machinery Company," March 27, 1909, PEC Minor Stations; EM to PEC, September 16, 1937 in "Structures and Generating Station Equipment," pp. 337-338, PEC; A brief history of the Electric Machinery Company of Minneapolis, Minnesota is The Early History of the Electric Machinery Manufacturing Company written by Herbert W. Meyer, February 15, 1973. Historical Research Inc., Minneapolis, Minnesota. (Typewritten)

[50] "Specifications: MPC Turbine Equipment," PEC Minor Stations; "Bulletin 110," Lombard Governor Company, October 1, 1908, p. 28, National Museum of American History, Washington, D.C.

[51] Drawing 62940 and "Electrical Specifications, Dam 4," PEC Minor Stations.

[52] Ibid.; Drawing 62942, PEC Minor Stations.

[53] "Electrical Specification, Dam 4," PEC Minor Stations.

[54] Ibid.; Electrical World, 50 (November 9, 1907); Shepherdstown Register, June 17, June 24, July 1, 1909; Martinsburg Herald, September 22, 1906; Martinsburg Statesman Democrat, September 21, 1909.

[55] Martinsburg Statesman Democrat, October 29, 1909; "Structures and Generating Station Equipment," PEC.

[56] "Petition to the Hon. W.H. Thomas from First National Bank of Hagerstown, Md," and "Order of Sale, Martinsburg Power Company," June 13, 1916, MPC Bankruptcy Case 551, FRC; Deed Book 117, Berkeley County, W.V., p. 156.

[57] Martinsburg Statesman Democrat, May 31, November 15, 1907; Atlas Engine Works to MPC, May 22, 1907 and T.T. Burchfield Company to MPC, May 24, 1907, PEC Historical File: MPC.

[58] "Specifications: MPC Turbine Equipment," and "Remodeling of the Water Power Plant at Dam No. 5," PEC Minor Stations; B.F. Groff to PL&PC, April 28, 1917, Leffel File AB-9592;

Martinsburg Statesman Democrat, October 19, November 23, 1906.

[59] *Martinsburg Statesman Democrat*, October 12, 1906, October 29, 1909; *Shepherdstown Register*, October 18, 1906; *Electrical World* 50 (November 9, 1907):943.

CHAPTER IV

YEARS OF CHANGE AND REORGANIZATION

URBAN GROWTH AND POPULATION SHIFTS

Changes in the economic structure of Berkeley and Jefferson counties continued to work to the advantage of the Martinsburg Power Company during the first decade of the twentieth century. Between 1900 and 1910, Berkeley County's population increased 12.9 percent, from 19,469 to 21,999. More significant than the increase in population was the dramatic shift in the rural to urban mix; the population of the rural areas of Berkeley County actually declined between 1900 and 1910 as families abandoned farms and migrated to Martinsburg. Berkeley County's 1910 rural population of 11,301 was 5.1 percent less than the county's 1900 rural population of 11,905. The move from farm to factory was clearly visible in the 41.4 percent increase in Martinsburg's population during the first decade of the 1900s. In 1910, 48.6 percent of Berkeley County, 10,698 people, lived in Martinsburg, an increase of 3,134 above the 38.9 percent of Berkeley County living in the city in 1900. [1] Adjacent Jefferson County, although still a predominantly rural county with 83.2 percent of its residents living in rural areas in 1910, also experienced a noticeable shift in the rural to urban balance. In Jefferson County, the rural population decreased by 2.3 percent and the urban population grew by 11.3 percent between 1900 and 1910. [2]

Economic activity in Berkeley County and Martinsburg, like the population, also displayed strong growth between 1900 and 1910. The focus of economic activity, mirroring the changes in the national economic structure, also changed as manufacturing was concentrated in smaller numbers of ever larger factories and industrial establishments. Between 1900 and 1910, the number of individual manufacturing establishments in Martinsburg declined a surprising 61.4 percent while, simultaneously, industrial employment grew 31.2 percent. In 1900, Martinsburg's 101 manufacturing establishments had employed 1,161 wage earners while in 1910 a mere 39 manufacturing establishments employed 1,523 employees. During this same time period, capital invested in buildings, equipment, and land grew 28.6 percent; payments for materials, taxes, and rent grew 73 percent; and the total sum of wages paid to manufacturing employees grew an astounding 88.2 percent. Most significantly, the value of the products manufactured in Martinsburg grew 78.3 percent as the city's mills and factories produced goods valued at $2,515,458 in the single year 1910. [3] The urbanization of the population, the expansion of investment in buildings and manufacturing equipment, the growth in the size of the mills and factories, and the increase in both the number and the income of wage earners all contributed to increased demand for the electricity generated by the Martinsburg Power Company. In 1911, responding to the need for larger volumes of more reliable electric service, the company installed a 1,000 horsepower coal fired steam boiler and a 1,000 kilowatt General Electric steam turbine generator in the Martinsburg generating station. [4]

The fiscal year ending June 30, 1912 was described by Martinsburg Power Company President Dr. S. N. Myers as "highly satisfactory," and at the July Board of Directors meeting, Myers, Vice-President S. A. Williams, and Treasurer F. E. Wilson were all reelected to their posts. H. B Shoemaker was reappointed to his position as Chief Engineer, however, James H. Harlow, the Chief Engineer of the Susquehanna Power Company, a Darlington, Maryland electric utility apparently in bankruptcy and administered in receivership by S. A. Williams, was named Secretary. [5]

Anticipating the continued growth of electric demand, the Board of Directors also discussed a proposal to install an additional turbine and a 750 kilowatt electric generator at the Dam 4 plant and "contemplated" the renovation and enlargement of the operable but badly deteriorated plant at Dam 5. [6] Pursuant to the Board's recommendation to expand the capacity of the Dam 4 plant, Secretary Harlow requested an appointment with Chesapeake and Ohio Canal Company General Manager G. L. Nicolson to discuss operations at Dam 4. Two months later Harlow requested another meeting with Nicolson to discuss the construction of a hydroelectric plant at the Canal Company's Dam 6 at Great Cacapon, West Virginia, thirty miles upstream from Dam 5. [7]

During the spring of 1913, with the Dam 5 plant often inoperable, Harlow proposed installing a series of two foot high plank "flash boards" across the tops of Dams 4 and 5. Although the primary purpose of the flash boards was to impound a small volume of water for use during low flow periods, the boards also allowed the plant's generating capacity to be significently increased by raising the head as much as two feet when the river was flowing normally. [8] The flash boards Harlow designed were to be held in place by one and one-quarter inch diameter steel rods driven into the cap of the dams. Harlow had designed the steel rods so that whenever water flowing over the flash boards was greater than two feet, the pins would bend or break and permit the release of the impounded water. [9] Harlow contacted both the U. S. Department of Agriculture and the Chesapeake and Ohio Canal Company to obtain the flood, low flow, and daily stream gauge records needed to design the flash boards, plan modifications of the hydroelectric plants, and generally assist the operation and regulation of the two plants. [10]

Legal questions involving the right of the Canal Company to raise the height of the water behind Dams 4 and 5 and the conscious efforts of the Canal Company's attorneys to keep Harlow "away from Mr. Bond," the general counsel, [11] delayed the erection of the flash boards during 1913 despite the "most severe" low flow problems ever experienced by the power company. [12] Low water flow and the deteriorated condition of the Dam 5 plant were not, however, the only problems confronting the management of Martinsburg Power during 1913.

ELECTRIC UTILITIES: COMPETITION, REGULATION, AND CONSOLIDATION

Competition for both the lucrative Martinsburg market and the numerous limestone and sand quarries scattered across Berkeley County began to intensify during 1913. At the beginning of 1909, the Winchester and Washington City Railway Company, pushing north from its Millville, Virginia hydroelectric plant, had entered Bakerton, West Virginia to supply electricity to the pumps, hoists, and air compressors of the Washington Building Lime Company limestone quarry. The Railway Company also moved west, stringing a line to Kearneysville to serve that town's numerous limestone quarries. [13] Responding to a request to supply electricity to the Standard Lime and Stone Company, located on the southern edge of Martinsburg, the Winchester and Washington Company petitioned Berkeley County for the right to erect a transmission line through Martinsburg to the Standard site and sell electricity. The franchise was issued in February 1909 and the transmission line between Kearneysville and Martinsburg was placed into service a few months later. [14]

The next opportunity for expansion came in 1911 when the Frederick Railway Company of Frederick, Maryland began negotiating with the Winchester and Washington City Railway Company for the purchase of electricity generated at Millville. When the negotiations collapsed after the Frederick Railway chose to build its own generating plant, the Winchester and Washington Company turned its attention toward Brunswick, Maryland and examined the feasibility of entering that town. [15] Unable to move into Brunswick, the Winchester and Washington purchased the Citizens Electric Light Company of Charles Town, West Virginia and, after deciding to abandon any railway operations, changed its name to the Northern Virginia Power Company. Continuing to expand, Northern Virginia Power acquired control of the Cacapon Power Company at the beginning of 1913. Cacapon Power, with a 400 kilowatt hydroelectric plant on the Cacapon River and a 625 kVa steam turbine plant in Berkeley Springs, West Virginia, was a small but profitable and growing utility obtaining the bulk of its income from the sale of electric power to more than a dozen sand and limestone quarries. A 23 mile long connection between the Northern Virginia Power line at Martinsburg and Cacapon Power's

Berkeley Springs generating station was begun in May 1913 and completed in February 1914. With the acquisition of Cacapon Power, Northern Virginia Power Company possessed four generating plants, two steam and two hydro, with a total value of approximately $600,000, and ranked ninth among West Virginia electric companies, five places behind the fourth ranking utility, the Martinsburg Power Company. Anticipating continued rapid growth, especially in sales of electric power to the Berkeley Springs quarries, a 1,050 horsepower S. Morgan Smith vertical shaft turbine direct connected to a 750 kilowatt vertical shaft "umbrella style" generator was installed in the Millville hydroelectric plant during 1913. Northern Virginia Power described the single runner, 133 rpm turbine as the "newest water wheel manufactured." [16]

Also during 1913, Emory L. Coblentz, a prominent Frederick County lawyer and the President of both the Central National Bank and the Frederick Railway Company, [17] merged eight gas, water, electric, and railway companies to create the Hagerstown and Frederick Railway Company. The merger brought into a single operating unit the Frederick and Hagerstown Power Company, Hagerstown Railway Company, Hagerstown and Myersville Railway Company, Hagerstown and Boonsboro Railway Company, Hagerstown and Northern Railway Company, Frederick Railway Company, Myersville and Catoctin Railway Company, and the Frederick Gas and Electric Company. The following year the Frostburg [Md.] Illuminating Company was added to the system. [18] The first issue confronting the Board of Directors of the newly formed corporation was the reorganization of the eight previously independent companies along more efficient, economical, and centralized lines. To assist in devising long range plans and managing daily operations, the Hagerstown and Frederick employed Sanderson and Porter, a nationally known, New York City based engineering and construction firm, as consulting and managing engineers and hired Max A. Pooler as General Manager. [19] Sanderson and Porter's representative, engineer John F. Wessel, immediately launched a vigorous campaign to increase the number of residential light and commercial and industrial power customers. He also sought to interconnect with and sell electric power to a number of independent Potomac River Valley electric companies. [20]

The State of West Virginia also entered the electric utility picture in 1913 when the West Virginia Public Service Commission was created to regulate the activities of water, gas, and electric companies operating within the state. The first annual report submitted by the Martinsburg Power Company to the West Virginia Public Service Commission disclosed that the company had 1,489 customers, all but two of whom received metered rather than flat rate service. Electric rates varied according to the type of service provided and, to encourage commercial consumption of electricity, kilowatt hour rates declined as the volume of consumption increased and electric power was one-third the cost of electric lighting. [21] In its first report to the West Virginia Public Service Commission, the management of the Martinsburg Power Company made no mention of the electric company's financial and operational difficulties.

OPERATING DIFFICULTIES AND FINANCIAL DISTRESS

The same droughts which wrought havoc upon the finances and operation of the Chesapeake and Ohio Canal also contributed heavily to the onset of the financial collapse of the Martinsburg Power Company. The extremely low flow of the Potomac continued into 1914 and severely reduced the output of the Dam 4 hydroelectric plant. With the Dam 5 hydroelectric plant inoperable and the Dam 4 plant generating below average amounts of current, Martinsburg Power was forced to rely almost exclusively on the Martinsburg generating station to meet customer demand. The heavy use of the coal fired steam generating plant caused an abrupt and dramatic increase in operating expenses during both 1913 and 1914, severely damaging the financial health of Martinsburg Power. With 80 percent of its income consumed by operating expenses, the company was unable to meet mortgage bond interest and sinking fund payments due during 1914 and forced to issue an additional $70,000 worth of mortgage bonds as collateral for a $30,000 loan. [22]

Nationally, as well as locally, 1915 was a difficult year for the hydroelectric industry and hydroelectric securities were extremely unpopular among investors in the stock and bond markets. Large scale commercial hydroelectric generation was scarcely more than twenty years old, and in the previous decade, plants with a total capacity of 600,000 horsepower had proven to be financial failures. [23] The financial difficulties of the Martinsburg Power Company were but one example of those faced by electric utilities relying heavily on hydroelectric generation.

Attempting to restore the profitability of the Martinsburg Power Company, stockholders, attending the January 1915 annual meeting, authorized the the formation of a "Reorganization Committee" to conduct the voluntary financial reorganization of the company. Participants deposited their stocks and bonds with the committee and received certificates of deposit in exchange. The five member committee, comprised of President Myers, Vice-President Williams, and three other stock and bond holders, was authorized to take any action contributing to the financial health of the electric company, including issuing new securities to finance desperately needed renovation of company facilities, negotiating the sale of the company, and distributing to creditors and participants in the reorganization effort the proceeds of any such sale. [24]

Shortly after its formation, the Reorganization Committee began negotiating the sale of the electric company to a Philadelphia engineering firm, Day and Zimmerman. [25] The firm, founded by two engineers, Charles Day and John E. Zimmerman, designed and built electric plants and transmission lines, collected information for banks on the financial "condition and prospects of enterprises seeking capital," and managed utilities in need of financial reorganization. [26] The Day and Zimmerman purchase agreement was completed in late February 1915, subject to the approval of the West Virginia Public Service Commission and the issuance of a new corporate charter. Day and Zimmerman intended to increase Martinsburg Power's capital assets from 500,000 to one million dollars and increase the generating capacity of the two Potomac River hydroelectric plants. For reasons never revealed, however, the Day and Zimmerman takeover was never culminated, although the engineering firm did agree to manage the finances of Martinsburg Power until October 1, 1915. [27]

After the failure of the purchase agreement, the Farmers National Bank of Annapolis, Maryland, seeking to collect overdue mortgage bond interest payments, initiated a chancery suit against Martinsburg Power. [28] On April 3, one month after the Farmers National Bank suit was filed, the Peoples Trust Company of Martinsburg secured two Berkeley County Circuit Court judgements against the electric company totalling $22,192 plus six percent interest until paid. [29] When Victor Cushwa, a prominent Williamsport, Maryland businessman, subsequently won a judgement against the electric company for $10,358, [30] the total of the liens against the property of Martinsburg Power rose to more than $32,500. One week later the State of West Virginia won a $25,720 judgement against Martinsburg Power, [31] pushing court ordered payments to more than $58,000.

With the electric company unable to meet interest and sinking fund payments, immediate financial reorganization and a major infusion of outside capital seemed the only way to avoid foreclosure and a court ordered liquidation of the electric company. With litigation impeding the voluntary reorganization and threatening to "dissipate the resources" of the electric company, [32] Judge A. G. Dayton of the United States District Court for the Northern District of West Virginia placed the electric company under receivership, appointed James H. Harlow and attorneys Clarence E. Martin and H. H. Emmert receivers, and charged them with the responsibility of completing the financial reorganziation effort. [33] The petition to place the electric company in receivership had been filed by stock and bondholders seeking to halt both the decline in the value of their securities and the deterioration of the tangible assets of the electric company. [34]

THE INTERVENTION OF THE HAGERSTOWN AND FREDERICK RAILWAY

The Hagerstown and Frederick Railway Company became a participant in the reorganization of the Martinsburg Power Company when Emory L. Coblentz, seeking to acquire a "controlling interest" in the electric company, began negotiating with the Reorganization Committee in April 1915. [35] Two months of private, unpublicized negotiations between Coblentz and the Reorganization Committee produced a tentative agreement outlining the role of the Hagerstown and Frederick Railway in the restructuring of Martinsburg Power. The agreement between Coblentz and the receivers stipulated that Coblentz, in actuality the Hagerstown and Frederick Railway Company, would pay $180,000 in exchange for $200,000 worth of Martinsburg Power Company bonds, purchase as much as $30,000 worth of non-voting stock for two-thirds of its par value, and lend the Martinsburg Power Company $20,000. In return for the $220,000 in cash put forth by the Hagerstown and Frederick, the railway company was to receive not only the bonds, but also three-fifths of the $250,000 of common stock to be issued by the reorganized electric company, bearing the name the Potomac Light and Power Company. The agreement provided that $100,000 of the cash would be used by the receivers for improvements to the deteriorating property with the balance used to satisfy the claims of creditors and bondholders unwilling to participate in the reorganization. Equally important for the deficit plagued electric company, the agreement provided for the establishment of an interconnection with and the reciprocal sale of electricity between the two companies. The agreement was contingent upon the full participation of creditors, the deposit of all the bonds and a majority of the stock with the Reorganization Committee, and, to give the Hagerstown and Frederick Railway clear legal title to the property, the uncontested foreclosure of the existing mortgages. [36]

Lacking the cooperation of all the creditors and the participation of all of the stock and bondholders, the Committee was unable to formally conclude the agreement with Coblentz and was forced to spend the next few months encouraging recalcitrant investors and creditors to support the Coblentz reorganization proposal. Coblentz, seeking to expedite the transaction, advised the Reorganization Committee that if his proposition was not "accepted within a reasonable time," it would be withdrawn. [37] When the People's Trust Company, seeking to collect the $22,192 previously awarded to it, petitioned the U. S. District Court to "garnish" funds deposited by Martinsburg Power at the local Merchants and Farmers Bank, the difficulties of successfully completing the reorganization plan increased. [38] To keep the reorganization plan alive and preclude the liquidation of the electric company, the Hagerstown and Frederick Railway Company purchased the claims of the bank, and, in so doing, made public the agreement between the Hagerstown and Frederick Railway Company and the Reorganization Committee. [39] The decision of the Executive Committee of the Railway Company's Board of Directors to purchase the Peoples Trust Company judgements against the Martinsburg Power Company was the only formal action taken during 1915 acknowledging the railway's participation in the electric company's reorganization.

Coblentz was not alone in seeking to gain control of the Martinsburg Power Company. The Northern Virginia Power Company, having previously been denied a franchise to operate within the city, saw the acquisition of the financially ailing electric company as the easiest way to enter Martinsburg. After Emory Coblentz succeeded in negotiating a contract with the Reorganization Committee, Northern Virginia Power sought to gain control of the reorganization process by purchasing Martinsburg Power Company bonds from anxious investors. [40]

Under the influence of the Hagerstown and Frederick's management, the receivers of the Martinsburg Power Company engaged the New York City based engineering firm of Sanderson and Porter to replace Day and Zimmerman as consulting and managing engineers of the electric company's properties and hired the railway company's electrical engineer, H. B. Baird, to replace F. W. Woodcock as electric company superintendent. [41] Guided by Sanderson and Porter and aided by a significant increase in hydroelectric generation during 1915, Baird cut operating costs, reduced the monthly deficits, and momentarily made the reorganization of the electric company plausible (see Tables 7 and 8). Contributing to the optimistic assessment of the company's renewed future was the August 1915 purchase of $48,500 worth of Martinsburg Power Company bonds by the Northern Virginia Power Company. [42] Viewing events, the Martinsburg World concluded: "With the Hagerstown and Frederick Railway Company having 75 percent of the securities and the Northern Virginia Power Company having 16 percent, it is beginning to look like business." The newspaper's interpretation of events, however, was inappropriately optimistic. [43]

REORGANIZATION IN BANKRUPTCY

Despite the vigorous personal efforts of Emory Coblentz to "bring matters to a definite conclusion," the reorganization effort remained stalled during the latter half of 1915. Competition between the Hagerstown and Frederick Railway and Northern Virginia Power for control of Martinsburg Power, the reluctance of all creditors and bondholders to participate in the reorganization scheme by depositing their notes and securities with the Reorganization Committee, and continuing monthly deficits all worked to thwart the success of the reorganization effort.

TABLE 7

MARTINSBURG POWER COMPANY FINANCES

	April 1915	May 1915	June 1915	July 1915	Aug. 1915	Sep. 1915	Oct. 1915	Nov. 1915	Dec. 1915	Jan. 1916	Feb. 1916	April 1916	May 1916	June 1916	July 1916
[1] Total Income	5,908	5,629	5,528	5,512	5,998	6,870	7,639	7,693	7,521	8,166	7,617	6,759	6,768	6,515	6,281
[2] Dam 4 Expenses	312	350	327	303	354	309	584	324	333	417	349	307	387	314	338
[3] Dam 5 Expenses	40	32	36	36	36	36	36	37	59	36	36	36	36	36	36
[4] Steam Plant Expenses	1,153	1,042	1,474	1,831	1,755	1,717	2,208	1,450	1,445	1,049	1,363	1,043	881	990	826
[5] Total Generation Expenses [2 + 3 + 4]	1,505	1,424	1,836	2,171	2,145	2,062	2,648	1,811	1,837	1,503	1,748	1,386	1,304	1,340	1,200
[6] Total Operating Expenses	3,046	3,137	3,149	3,324	3,394	3,445	4,179	2,894	3,088	2,878	2,961	2,693	2,602	2,570	2,744
[7] Percent of Income [line 1] to Operations	51.6	55.7	57.3	60.3	56.6	50.0	54.7	37.0	41.0	35.0	38.8	39.8	38.4	39.4	43.6
[8] Operations as a % of Operating Expenses	72.5	80.8	87.6	92.1	90.1	90.9	86.6	93.7	94.9	84.0	----	----	----	----	----
[9] Maintenance as a % of Operating Expenses	27.5	19.2	12.4	7.9	9.9	9.1	13.4	6.3	5.1	16.0	----	----	----	----	----

Source: Martinsburg Power Company Bankruptcy Proceedings, Case 551.

TABLE 8

MARTINSBURG POWER COMPANY ELECTRIC OUTPUT

	June 1915	July 1915	Aug. 1915	Sep. 1915	Oct. 1915	Nov. 1915	Dec. 1915	Jan. 1916	Feb. 1916	April 1916	May 1916	June 1916	July 1916
Total Output (kWh)	292,125	304,700	337,125	366,675	395,500	387,925	413,750	459,000	472,045	401,750	416,350	412,125	390,400
Cost per kilowatt hour	.00628	.00712	.00637	.00765	.00673	.00467	.00445	.0032	.0036	.0034	.003049	.00318	.0031
Steam turbine output (kWh)	60,175	213,450	181,875	130,775	160,925	195,150	73,350	65,600	74,095	248,350	109,600	43,025	52,600
Cost per kilowatt hour	.0245	.00858	.00965	.01313	.0126	.00743	.0197	.016	.0184	.0042	.00804	.023	.0157
Percent of total output	20.6	70.1	53.9	35.7	40.7	50.3	17.7	14.3	15.7	61.8	26.3	10.4	13.5
Dam 4 output (kWh)	231,950	91,250	155,250	235,900	234,575	192,775	340,400	393,400	397,950	153,400	306,750	369,100	337,800
Cost per kilowatt hour	.00141	.00333	.00228	.00131	.00249	.00168	.000979	.00106	.000876	.002	.001267	.00085	.0011
Percent of total output	79.4	29.9	46.1	64.3	59.3	49.7	82.3	85.7	84.3	38.2	73.7	89.6	86.5

Source: Martinsburg Power Company Bankruptcy Proceedings, Case 551.

The deficit for the year 1915 totalled $13,412.49. [44] By 1916, raising the capital required to upgrade the system, pay creditors, and purchase the stocks and bonds of investors unwilling to participate in the reorganization plan seemed an impossible task.

During January and February of 1916, despite record breaking sales of electricity, Martinsburg Power reported a profit of only $1340.63, and in March the balance sheet revealed a deficit of $1053.66, leaving the company with an an extremely small profit of $286.97. [45] When two transformers, one at the Dam 4 plant and one in Martinsburg, burned out, the electric company was forced to scrape together $2,000 to replace them. Other damaged equipment, like the Electric Machinery generator and the governors at the Dam 4 plant, went unrepaired because of the lack of money. [46] The physical condition of the system both reflected upon and contributed to the failure to show a profit since 1913. The Dam 5 plant, removed from service in 1912, remained inoperable, the Dam 4 plant required an estimated $5,000 in repairs, the Martinsburg generating station needed improvements costing $2,000 and the transmission and distribution network required $15,000 worth of repairs and improvements. Perhaps the most embarrassing fact was that with the Dam 5 plant out of operation theives had stolen much of the copper transmission line between the plant and Martinsburg. Because of the "crippled condition" of the system, Martinsburg Power was forced to turn away new customers whose electric power purchases would have materially helped the electric company's finances. [47]

With the physical condition of the system deteriorating rapidly, the reorganization effort stalled by bondholders opposed to the Reorganization Committee, and, most importantly, debts of $621,735.39 exceeding tangible assets of $597,211.13, stockholders who gathered together at the 1916 annual meeting voted to file for bankruptcy and seek reorganization under the protection of the court. [48] Responding to Martinsburg Power's banruptcy petition, Judge Dayton declared the electric company bankrupt, appointed Judge Wilbur H. Thomas as bankruptcy referee and Clarence E. Martin as Trustee, authorized the expenditure of $8,600 for emergency repairs, and, to settle conflicting estimates of the company's worth, appointed three appraisers to conduct an official appraisal. [49] The appraisers assessed the value of the company at $598,817.39:

Dam 4 Hydroelectric plant	236,700
Dam 5 Hydroelectric plant	30,300
Martinsburg electric plant	120,108.55
High-tension transmission lines	35,775
Distribution lines	77,034.12
Office equipment	5,500

Cash and accounts receivable	52,399.72
Capitalization of riparian rights	15,000
Rights-of-way	26,000
Total	598,817.39 [50]

Upon completion of the appraisers evaluation, Trustee Martin petitioned Judge Thomas to sell the property. [51] The Rumseys, who had acquired $50,000 worth of Martinsburg Power Company bonds as payment for the installation of electric generating equipment at Dam 4, Dam 5, and the Martinsburg generating stations, temporarily delayed the sale when they filed a suit to withdraw their bonds from the pool of securities held by the Reorganization Committee. Other investors, fearing they would receive inadequate compensation for their bonds and growing restless at the difficulty and lack of tangible progress in halting the further deterioration of the utility's equipment and financial condition, sought to withdraw from the Reorganization Committee and sell their securities individually. [52] The Executive Committee of the Board of Directors of the Hagerstown and Frederick Railway Company concluded that with so many financial and legal difficulties remaining to be resolved it was neither wise nor prudent to raise the large amount of additional cash needed to sustain the reorganization effort and in May 1916 terminated its officially sanctioned effort to reorganize and acquire the Martinsburg Power Company. Emory L. Coblentz, however, enlisted the assistance of two business associates and launched a personal effort to acquire the Martinsburg Power Company. [53]

On May 25, Trustee Martin, acknowledging that the electric company was unable to make interest and sinking fund payments on $570,000 worth of 1904, 1907, and 1913 mortgage bonds, once again petitioned bankruptcy referee Thomas for permission to foreclose the mortgages and sell the electric company. [54] On June 14, Judge Thomas consented to Martin's request. [55] Seeking to avoid an interruption of service to customers and permit the eventual purchaser to continue operating the property, as well as maximize the returns to creditors and bondholders, Judge Thomas ordered the company sold as a single unit free of liens, transferred the liens against the mortgage bonds to the funds obtained from the sale of the property, and ordered that the 1904 and 1907 mortgage bonds be retired before unsecured creditors could be paid. [56] One week later, "after months of litigation, hearings, and conferences," United States District Court Judge Taylor dismissed objections to the sale filed by a minority of the bondholders, among them the Northern Virginia Power Company, and affirmed Thomas's order requiring the sale of the Martinsburg Power Company at a public auction. [57]

Judge Thomas scheduled the sale for July 22, 1916 and required a $50,000 deposit from each prospective bidder. N. W. Seabrease of Philadelphia, representing Day and Zimmerman; L. F. Cooper of Winchester, Virginia, representing the Northern Virginia Power Company, and General Manager of the Hagerstown and Frederick Railway Max A. Pooler, representing Emory Coblentz and the members of the Reorganization Committee, posted the deposit. [58] The Court also ordered that the property yield no less than 75 percent of the appraised value minus cash on hand and, consequently, the bidding began with an offer of $427,665. At 2:45 that afternoon, after 425 bids had been voiced, M. A. Pooler offered the winning bid of $575,000. [59]

FOOTNOTES: CHAPTER IV

[1] Thirteenth Census of the United States, 1910, pp. 1032.

[2] Ibid., p. 1034.

[3] Ibid., p. 1328-1329; Twelth Census of the United States, 1900, pp. 944-945, 948-949.

[4] Martinsburg Herald, February 25, 1911.

[5] Martinsburg Evening Journal, July 26, July 29, 1912; J.H. Harlow to G.L. Nicolson, January 14. 1913, C&O Papers, NA.

[6] Martinsburg Evening Journal, July 26, July 29, 1912.

[7] J.H. Harlow to G.L. Nicolson, January 14, 1913, March 12, 1913, June 14, 1913, C&O Papers, NA.

[8] J.H. Harlow to G.L. Nicolson, May 8, 1913, June 9, 1913, C&O Papers, NA; Agreement MPC and C&O, July 9, 1913, "Potomac Development Volume 1," PEC.

[9] Ibid.; J.H. Harlow to G.L. Nicolson, May 8. 1913, C&O Papers, NA.

[10] J.H. Harlow to G.L. Nicolson, June 14, 1913, June 30, 1913, C&O Papers, NA.

[11] J.H. Harlow to G.L. Nicolson, September 25, 1913, G.R. Webber to G.L. Nicolson, November 11, 1913, C&O Papers, NA.

[12] J.H. Harlow to G.L. Nicolson, September 20, 1913, C&O Papers, NA; Martinsburg World, September 15, 1913; Agreement MPC and C&O, "Potomac Development Volume 1," PEC.

[13] Shepherdstown Register, March 25, 1909; Electrical World 69 (December 5, 1908):1266; Electrical World (February 11, 1909):426; PEC Historical File: W&WCRC, December 8, December 14, 1908.

[14] Martinsburg Statesman Democrat, February 19, 1909; W&WCRC Historical File, December 14, 1908, February 26, 1909.

[15] Northern Virginia Power Company Board of Directors Minutes, 1913-1926, July 15, 1913, PEC; PEC Historical File: W&WCRC, October 3, October 17, 1911, July 16, December 2, 1912.

[16] NVPC Minutes, July 15, October 9, November 12, 1913, June

30, July 20, 1914; Martinsburg World, May 12. 1913; PEC Historical File: W&WCRC, January 27, February 11, March 12, April 30, 1913; WVPSC, First Annual Report, pp. 440. 448.

[17] National Cyclopaedia of American Biography XXXI University Microfilms, Ann Arbor, Michigan, 1967, p. 56.; History of Frederick County Volume I, p. 532, Volume II, p. 776.

[18] Maryland Public Service Commission, Report of the Public Service Commission: 1914 (Baltimore: Kohn & Pollock, 1915), pp. 244-245; Moody's Analysis of Investments, p. 1434; Poor's Manual of Public Utilities, 1918, p. 2025; PEC Historical File: H&F, April 21, 1913.

[19] Hagerstown and Frederick Railway Company, Executive Committee Minutes, April 20, May 21, 1914, PEC.

[20] H&F Minutes, June 6, July 16, August 20, November 2, 1914; NVPC Minutes July 20, 1914, July 20, 1915.

[21] WVPSC, First Annual Report, 1914, p. 450.

[22] "Petition to the Hon. A.G. Dayton from Clarence E. Martin," March 10, 1916, "Petition to the Hon. W.H. Thomas, Referee, from Safe Deposit and Trust Company of Baltimore, Maryland," no date, and "Order of Sale, MPC," June 13, 1916, MPC Bankruptcy Case 551, FRC.

[23] National Electric Lighting Association, Proceedings of the 1915 Annual Convention, pp. 284-285.

[24] "MPC Reorganization Committee Agreement," January 14, 1915, MPC Bankruptcy Case 551, FRC; H&F Minutes, September 1, 1916.

[25] Martinsburg World, March 1, 1915.

[26] The National Cyclopaedia of American Biography XXVI 1937, pp. 96-97; XXXVIII 1953, pp. 608-609.

[27] Martinsburg World, March 1, 1915; "Receiver's Report," August 17, 1916, MPC Bankruptcy Case 551, FRC.

[28] "Petition to the Hon. A.G. Dayton from C.E. Martin," March 10, 1916, MPC Bankruptcy Case 551, FRC.

[29] "Peoples' Trust Versus MPC," May 14, 1915, MPC Bankruptcy Case 551, FRC; Martinsburg World, April 23, 1915.

[30] "V.M. Cushwa and D.K. Cuskwa Versus MPC," May 14, 1915, "Petition to the Hon. W.H. Thomas from V.M. and D.K. Cushwa," no

date, and "Order of Sale, MPC," June 13, 1916, MPC Bankruptcy Case 551, FRC.

[31] "Petition to the Hon. W.H. Thomas from A.A. Libby, Attorney General of the State of West Virginia," May 21, 1915, MPC Bankruptcy Case 551, FRC.

[32] Martinsburg World, April 23, 1915; "Order of Sale, MPC," June 13, 1916, MPC Bankruptcy Case 551, FRC.

[33] Martinsburg World, April 23, 1915.

[34] Ibid.

[35] H&F Minutes, August 17, 1915, September 1, 1916.

[36] Ibid.; Martinsburg World, February 2, 1916; H&F Annual Report, December 31, 1915; J.H. Harlow to G.L. Nicolson, September 16, 1915, C&O Papers, NA.

[37] H&F Minutes, April 22, May 3, May 21, July 12, July 30, 1915, September 1, 1916.

[38] Martinsburg World, July 7, 1915.

[39] Martinsburg World, August 13, August 28, 1915; H&F Minutes, August 17, 1915; "Petition to the Hon. W.H. Thomas from Mechanics Loan and Savings Institute, Hagerstown, Md.," August 27, 1915, "People's Trust Versus MPC," May 14, 1915, and "Order of Sale, MPC," June 13, 1916, MPC Bankruptcy Case 551, FRC.

[40] NVPC Minutes, March 16, April 27, May 28, July 29, October 19, 1915.

[41] H&F Minutes, September 2, November 19, 1915; H&F Annual Report, December 31, 1915; "Receiver's Report," August 17, 1916, MPC Bankruptcy Case 551, FRC; Martinsburg World, August 28, 1915.

[42] "Receiver's Report," August 17, 1916, "Report of the Trustee," no date, MPC Bankruptcy Case 551, FRC; NVPC Minutes, July 29, 1915.

[43] Martinsburg World, August 2, 1915.

[44] Martinsburg World, February 14, 1916; H&F Minutes, January 10, January 27, September 1, 1916; "Petition to the Hon. A.G. Dayton from C.E. Martin," March 10, 1916, MPC Bankruptcy Case 551, FRC.

[45] Ibid.

[46] Ibid.; S&P to C.E. Martin, June 26, 1916, H.B. Baird to C.E. Martin, June 26, 1916, and "Petition to the Hon. W.H. Thomas, Referee, from C.E. Martin," July 15, 1916, MPC Bankruptcy Case 551, FRC.

[47] "Petition to the Hon. A.G. Dayton from C.E. Martin," March 10, 1916, "Petition to Hon. W.H. Thomas from C.E. Martin," April 1916, "Petition to the Hon. W.H. Thomas from C.E. Martin," July 15, 1916, MPC Bankruptcy Case 551, FRC; <u>Martinsburg World</u>, August 7, 1916.

[48] <u>Martinsburg World</u>, January 4, February 14, 1916; "Petition and Schedule of the Martinsburg Power Company, Bankrupt," February 12, 1916, MPC Bankruptcy Case 551, FRC.

[49] Ibid.; <u>Martinsburg Evening Journal</u>, February 14, 1916; <u>Martinsburg World</u>, February 12, February 14, 1916; <u>Martinsburg Journal</u>, February 15, February 28, March 6, 1916; "Petition to the Hon. A.G. Dayton from C.E. Martin," March 10, 1916, MPC Bankruptcy Case 551, FRC.

[50] <u>Martinsburg Evening Journal</u>, March 1, 1916.

[51] <u>Martinsburg Journal</u>, April 1, 1916.

[52] <u>Martinsburg Journal</u>, April 10, April 29, 1916; <u>Martinsburg World</u>, April 7, April 8, April 10, 1916; newspaper article "Important Points in Power Company Suit," MPC Scrapbook, PEC; H&F Minutes, September 1, 1916.

[53] Ibid.

[54] <u>Martinsburg World</u>, June 14, 1916; "Order of Sale," June 13, 1916, "Petition for Review," June 17, 1916, and "In the Matter of the Martinsburg Power Company Bankruptcy," August 16, 1916, MPC Bankruptcy Case 551, FRC; newspaper article "Power Company Asks Authority to Sell," MPC Scrapbook, PEC.

[55] <u>Martinsburg World</u>, June 14, 1916; newspaper article "MPC To B Sold At Auction," MPC Scrapbook, PEC; "In the Matter of the Martinsburg Power Company Bankruptcy," August 16, 1916, MPC Bankruptcy Case 551, FRC.

[56] Ibid.; "Order of Sale, MPC," June 13, 1916, MPC Bankruptcy Case 551, FRC.

[57] Ibid.; "Response to Petition," June 5, 1916, "Response to Petition," NVPC, June 6, 1916, and "Report of the Trustee," no date, MPC Bankruptcy Case 551, FRC; <u>Martinsburg World</u>, June 14, June 20, 1916; newspaper article "Power Company Sale Is Affirmed By Court," MPC Scrapbook, PEC.

[58] "Report of the Trustee," no date, "Report of the Trustee to the Hon. W.H. Thomas," January 10, 1917, and "Order of Sale, MPC", June 13, 1916, MPC Bankruptcy Case 551, FRC; Martinsburg World, July 22, 1916; The Baltimore Sun, July 23, 1916; newspaper article dated July 22, 1916, MPC Scrapbook, PEC; NVPC Minutes, July 18, 1916; H&F Minutes, September 1, 1916.

[59] "Report of the Trustee," no date, "In the Matter of the Martinsburg Power Company Bankruptcy," August 16, 1916, MPC Bankruptcy Case 551, FRC; Martinsburg World, July 22, 1916; The Baltimote Sun, July 23, 1916; newspaper article dated July 22, 1916, MPC Scrapbook, PEC.

CHAPTER V

THE POTOMAC LIGHT AND POWER COMPANY

INCORPORATION

On August 7, 1916, a group of Maryland investors met in the Martinsburg office of the Martinsburg Power Company to organize the Potomac Light and Power Company. The assembled investors formed the Board of Directors and included: Joseph J. Hock, President; E. R. Haggett, Vice-President; Warren J. Platt, Secretary; E. L. Wade, Treasurer; Frank J. Monius, Assistant Treasurer; and William J. Martin and Harry B. Handley Jr. Those present at the meeting voted to issue $600,000 worth of stock and $425,000 worth of bonds, use the bulk of these securities to purchase the Martinsburg Power Company property held by M. A. Pooler, and connect the lines of the Potomac Light and Power Company to those of the Hagerstown and Frederick. [1] Three days later the West Virginia Secretary of State approved the Potomac Light and Power Company's charter of incorporation and request to issue $1,025,000 worth of securities. [2] On August 16, creditors accepted and bankruptcy referee Thomas approved the sale of the Martinsburg Power Company using the newly issued Potomac Light and Power Company stocks and bonds as payment. [3]

Two days after the transfer of assets from Pooler to the Potomac Light and Power Company was completed, the stockholders of the new company gathered in Baltimore, Maryland and elected a new slate of officers and directors. Emory L. Coblentz was elected President, and former Martinsburg Power Company President Dr. S. N. Myers was elected Treasurer. Interim president J. J. Hock was elected Vice-President and interim treasurer E. L. Wade was named Secretary. Former Martinsburg Power Company General Manager H. B. Baird was elected Assistant Secretary and F. H. Jacobs, F. H. Warfield, and two prominent Martinsburg residents, Gray Silver and F. E. Wilson, joined the Board of Directors. [4]

The election of Emory Coblentz as President and four of his business associates to the Board of Directors, completed the de facto consolidation of the Potomac Light and Power Company with the Maryland chartered railway company. Upon assuming their new responsibilities, the officers and directors authorized Sanderson and Porter to continue acting as consulting engineers of the former Martinsburg Power Company property and proposed exchanging a majority of Potomac Light and Power Company stock for Hagerstown and Frederick Railway bonds. [5] At the next meeting of the Hagerstown and Frederick Railway Board of Directors, Coblentz proposed and the directors subsequently ratified both the stock purchase and the agreement to connect Potomac Light and Power's system to the generating station at Security, Maryland with the acknowledgement that both actions "would materially benefit and profit the Hagerstown and Frederick Railway Company." [6]

COMPETITION AND CONFRONTATION

The participation of the Hagerstown and Frederick Railway Company in the formation and operation of the Potomac Light and Power Company encouraged public speculation that the management of the railway was preparing to amalgamate electric and railway companies throughout the region. Under the auspices of Hambleton and Company, the New York investment bank associated with the Hagerstown and Frederick, the Cumberland Valley Utilities Company was formed in 1916. The formation of Cumberland Valley Utilities and a concurrent visit to Berkeley County of representatives of the Fidelity Trust Company of Baltimore, Hambleton and Co., and Sanderson and Porter, intensified the speculation that Emory Coblentz, despite his denials, was moving aggressively to consolidate public utilities throughout the Potomac River Valley. [7]

In September 1916, less than a month after acquiring a majority of the stock of the Potomac Light and Power Company, Coblentz had unsuccessfully attempted to acquire a majority of the stock of the Northern Virginia Power Company, the only competing electric company in Berkeley and Jefferson counties. Northern Virginia Power's rejection of Coblentz's purchase proposal initiated a vigorous competition for the Martinsburg market. Having lost the public bidding for the bankrupt Martinsburg Power Company and seeing Potomac Light and Power increase customers and strengthen its competitive position with rate reductions of between 5 and 12 percent, Northern Virginia Power renewed its effort to enter Martinsburg. [8] The company's Supertindent, D. M. Swink, wrote to President Lewis F. Cooper in February 1917:

> ...we must be prepared for a most active competition in the vicinity of Martinsburg, both from an operating stand-point and from the influence of prominent people in Martinsburg. I think it most necessary to retain one or more attorneys and also to get the active interest of some prominent man in Martinsburg. I believe that even underhand means will be taken by the Martinsburg Company [Potomac Light and Power Company] to take business away from us and influence our power customers.
>
> I also think it desirable to apply for a franchise in the City of Martinsburg, and to keep the matter agitated even though it might be impossible to get such a franchise. The more that we can do to influence public opinion and harass the above company will make it

> quicker for the two companies to get a better understanding of what their company [Potomac Light and Power] proposes to do in the matter of cutting rates. [9]

Following Swink's advice, Cooper hired Martinsburg attorney H. H. Emmert to prepare and publicize the company's application for a franchise to distribute electricity within the city limits. [10]

The effort to influence public opinion began on May 1, when both companies began placing front page advertisements; Potomac Light and Power using the Martinsburg World and Northern Virginia Power using the Martinsburg Evening Journal. Both companies ran daily half and full page ads until the end of May and these public exchanges quickly escalated into an intense war of words. Potomac Light represented itself as a local firm, labeled Northern Virginia Power a "foreign corporation, chartered in the State of Virginia," and warned: "If Northern Virginia Power takes or gets any of our business, Winchester labor and Winchester capitalists will benefit and Martinsburg will correspondingly suffer." [11] Northern Virginia Power countered that Potomac Light was operated by Frederick and Baltimore, Maryland and New York capitalists, promised brighter, steadier lights and more accurate meters, and boldly asserted that its low rates and ample generating capacity would finally induce an electric railway line to reach Martinsburg. When Northern Virginia Power argued that competition would produce lower rates and better service, Potomac Light countered that competition would only bring an inefficient duplication of poles and distribution lines and that West Virginia Public Service Commission regulations, not competition guaranteed reliable, reasonably priced service from "natural monopolies" such as electric utilities. [12] The heated debate between the two companies flared not only in the newspapers, but also before civic associations, such as the Martinsburg Businessmen's Association, and before the weekly meetings of the Mayor and City Council until September 6, 1917 when Northern Virginia was granted the long sought franchise; despite the last minute promise of the Potomac Light and Power Company to reduce rates a second time at the end of the year. [13]

Potomac Light and Power's fear that Northern Virginia Power would capture a large share of the Martinsburg market was legitimate. Northern Virginia Power was a profitable and rapidly growing competitor. During 1914 and 1915, when Martinsburg Power had lost money, Northern Virginia earned record breaking profits. Likewise, between July 1914 and 1916, when the number of customers served by Martinsburg Power grew only 10 percent, Northern Virginia Power expanded by 74.6 percent. Including three efficient vertical shaft turbines and direct connected generators, Northern Virginia Power maintained approximately 4,000 kilowatts of hydroelectric and 2,000 kilowatts of steam turbine capacity, compared to Potomac Light and Power's total capacity of 2,500 kilowatts. [14]

THE NEED FOR ADDITIONAL HYDROELECTRICITY

As the successor of the Martinsburg Power Company, Potomac Light and Power operated a system with a history of financial difficulty, a reputation for less than reliable service, and a need for improvements costing as much as $100,000. Coblentz realized that if Potomac Light and Power was to improve its competitive position, avoid losing its customers, and continue to grow, it had to provide "unusually satisfactory service." [15] With Dam 5 inoperable and the connection with the Hagerstown and Frederick not yet under construction, Potomac Light and Power lacked the generating capacity to take on new customers without "sacrificing existing service" and further "injuring and jeopardizing its reputation." [16]

The Hagerstown and Frederick had its own concern with inadequate generating capacity. The success of the aggressive efforts to expand electricity sales, begun in 1914 by Sanderson and Porter's representative to the Hagerstown and Frederick, increased more than just the income of the railway company. During the latter half of 1915, and the first nine months of 1916, the Hagerstown and Frederick averaged approximately ten new commercial, thirty-seven new residential, and four new industrial power customers per month. [17] The load at the Hagerstown and Frederick's Security, Maryland coal fired electric generating station began showing significant increases as early as July 1915. Output during January 1916 was 20 percent higher than the same month in 1915 and February's output was 34 percent greater than in the preceeding year. In October of 1916, output at Security climbed to an unprecedented 1,355,250 kilowatt hours, 90 percent higher than the 646,250 kilowatt hours produced by the plant in October 1915. [18] During November 1916, with demand growing by as much as seven percent a week, Security's peak output reached a record breaking 75 percent of its installed capacity and the Hagerstown and Frederick faced the possibility that demand would very soon exceed the plant's generating capacity. [19] The rapidly increasing demands upon the Security generating station prompted the Hagerstown and Frederick to more than double the plant's 4,000 kilowatt capacity by installing a 5,000 kilowatt steam turbine generator during 1916. [20]

Control of the Potomac Light and Power Company afforded the Hagerstown and Frederick the opportunity to combine the output of Potomac Light's two hydroelectric and single coal fired electric generating stations with the Hagerstown and Frederick's Security steam plant. As early as April 1915, the Hagerstown and Frederick, seeking primarily to purchase the relatively less expensive, surplus current produced by the Dam 4 hydroelectric plant, had initiated negotiations with the Martinsburg Power Company for a reciprocal power contract. The continuing difficulties experienced during the reorganization of Martinsburg Power, however, precluded rapid completion of an electrical interconnection between the two companies and the Hagerstown and Frederick was left dependent on its Security, Maryland coal fired steam turbine electric generating station for all of the company's generating capacity.

Three interrelated developments pushed the Hagerstown and Frederick and its corporate subsidiary, Potomac Light and Power, toward a serious consideration of reconstructing the Dam 5 hydroelectric plant: increasing load demands upon the Security steam plant; rapidly rising coal prices; and the diminishing availability of a steady and sufficient supply of coal. Coal prices first began rising during March 1916, climbing from $1.22 to $1.37 a ton at the mine. The management of the Hagerstown and Frederick contracted for coal for the year October 1916 to September 30, 1917 at $1.80 per ton at the mine, a 43 cent per ton increase over the previous contract price. A few days later, a supplemental coal contract for the additional coal necessitated by Security's growing output demanded $1.95 per ton at the mine. Less than one week after the Hagerstown and Frederick signed the $1.95 per ton coal contract, coal on the open market soared to $2.85 a ton at the mine. Soaring coal prices even prompted the railway company to investigate the benefits of purchasing a coal mine to assure the Security plant an adequate and reasonably priced supply of fuel. [21]

Compounding the problem of high prices was a growing scarcity of coal, exacerbated by a railroad car shortage, during the latter part of 1916 and all of 1917. During December of 1916, the Hagerstown and Frederick received only 70 percent of the coal the company had contracted to purchase. January and February of 1917 were even more dismal, with Security receiving only 41 and 66 percent of the coal contracted and this at a cost of $4.05 a ton delivered to the plant. By July supplemental contracts for coal, when obtainable, found coal costing as much as $3.40 a ton at the mine and as much as $5.50 per ton when purchased on the open market. [22]

Rising coal prices helped push the cost of generating electricity at Security up 178 percent during January 1917. A 75 percent increase in electrical output and other non-fuel operating economies offset some of this dramatic increase, however, the cost of generating electricity at Security rose 35 percent, from .0066 to .0089 cents per kilowatt hour. [23] To offset the erosion in income arising from increased fuel costs, the Hagerstown and

Frederick resorted to raising fares on its railway lines. Throughout 1917, the price and availability of coal remained the "chief concern" of the company's managers. [24] In Martinsburg, Potomac Light and Power's coal costs also more than doubled. Fully compensating for the increase in fuel costs would have required increasing electric rates by 50 percent and, with the majority of electric power contracts expiring and Northern Virginia Power stringing lines and soliciting customers throughout the city, Potomac Light and Power desperately searched for ways to cut operating expenses and avoid raising rates. [25]

THE PLAN TO REBUILD THE PLANT AT DAM 5

The answer to the Hagerstown and Frederick's dual concern, providing increased generating capacity and, simultaneously, reducing coal consumption and lowering operating expenses, lay with the Potomac Light and Power Company's two hydroelectric plants. Responding not only to its own needs, but also those of its corporate parent, Potomac Light and Power began investigating the feasibility of reconstructing the Dam 5 hydroelectric plant in January of 1917. [26]

As early as 1912, Martinsburg Power had begun developing plans to rebuild and enlarge the intermittently inoperable Dam 5 plant. The onset of the electric company's financial difficulties and eventual bankruptcy, however, precluded the implementation of the renovation plans. Within one month after purchasing the property of the Martinsburg Power Company, Potomac Light and Power began making temporary repairs to the plant. [27] Engineers from the Hagerstown and Frederick Railway Company and Sanderson and Porter inspected the site on at least two occasions during 1916 and at the January 1917 meeting of Potomac Light and Power's stockholders, the Board of Directors authorized the employment of Sanderson and Porter to conduct a "thorough survey of the Company's property," and assist the Board in planning improvements and major capital expenditures. [28]

The result of Sanderson and Porter's engineering evaluation was transmitted to E. L. Coblentz on March 12, 1917. Sanderson and Porter's engineer, J. F. Wessel, advised Coblentz that "having carefully investigated and studied all available sources of power supply and their respective construction and operating costs...your interests would be best served by reconstructing and further developing the power station at Dam 5." [29] Wessel described the existing station as in "very bad condition," and recommended its replacement with a "modern steel and concrete structure." [30] He reported that only two of the station's three water wheels were serviceable and rejected the reconstruction of the station using the installed water wheels and rope driven generator. While concluding that the cost of the reconstruction option was the lowest of the various alternatives, Wessel also reported that the efficiency of the rebuilt rope drive system:

> would be very low compared with a modern vertical shaft water wheel, direct connected to a modern revolving field, alternating current generator, the difference being about 20 percent. Considering the size of the installation, this difference would be equivalent to over 150 horsepower which would be lost in the operation of the old style vertical wheels with a counter shaft and rope drive to the generator. [31]

The most efficient course of action, according to Wessel's report, was to raze the existing structure and erect a building that would house two 700 kilovolt-ampere (kVA) generating units, each direct-connected to an 800 horsepower vertical shaft turbine. Wessel estimated the total cost of the project, excluding engineering fees, at $157,773. He also recommended rebuilding the 14 mile long transmission line between Dam 5 and Martinsburg to handle the new generating load and estimated the cost of this project at $12,000. Finally, he buttressed the case for a new plant at Dam 5 with the conclusion:

> The installation of one unit [at Dam 5] and the reconstruction of the transmission line would enable the Company [Potomac Light and Power] to supply additional power and dispense with the operation of the steam plant at Martinsburg except under very unusual conditions. We estimate that upon the installation of one 700 kVA generating unit at Dam no. 5 and the reconstruction of the transmission line, the annual savings in the operation of the steam plant will be about $10,000.
>
> The installation of two units would more than double the present hydro-electric capacity of the Company. The addition of the second unit at Dam no. 5 would add 100 percent to the capacity of the station at about 30 percent additional cost, without material increase in the operating expenses. The Company could then readily supply additional power to such prospective customers as the Nessle Quarries and the Security Lime and Cement Company's quarries at Berkeley.
>
> When the tie line between the Potomac Light and Power Company and the Hagerstown and Frederick Railway Company is completed the two generating units at Dam no. 5 could be operated advantageously during almost the entire year. As the demand for power in West Virginia increases the Company would then sell less primary power to the Hagerstown and Frederick Railway Company. [32]

Wessel concluded his report by indicating that Sanderson and Porter was immediately prepared to undertake the construction of the entire plant. [33]

Following a general discussion of the recommendations contained in Wessel's letter, a committee consisting of President Coblentz, Frank Jacobs, and Gray Silver was appointed to evaluate the merits of the proposal, the costs and methods of financing the project, and the details involved in negotiating a construction contract. [34]

After "carefully considering the matter and the difficulty of obtaining bids for construction at set prices, because of the uncertainty of the market for materials and supplies used in construction" and with the "recommendation of Sanderson and Porter as consulting engineers," the committee recommended that the Potomac Light and Power Company proceed with the project under the supervision of Sanderson and Porter. [35]

Sanderson and Porter's original design called for the Dam 5 plant to house three turbine-generator units, however, Potomac Light and Power's desire to reduce costs "as much as possible," prompted the consulting engineers redesign the plant to accommodate only two direct connected turbine-generator units. [36] Sanderson and Porter also adopted a new layout for the plant, reducing the distance between the centerlines of the two turbines and shrinking the plant's overall dimensions to "meet existing conditions, that is the location of the mill walls, etc." which the engineers hoped to disturb "as little as possible on account of the additional cost of rebuilding them." [37]

Because both Potomac Light and Power and the Hagerstown and Frederick sought Dam 5 plant's low cost hydroelectricity as soon as possible, expediting construction was as crucial as minimizing cost. Anticipating the difficulty of transporting thousands of tons of construction material and power house equipment from Martinsburg by road, Sanderson and Porter chose to receive both construction materials and generating equipment at Williamsport, Maryland. Here the supplies and equipment could be loaded onto barges, towed seven miles up the C&O Canal, and ferried across the Potomac to the Dam 5 site. Seeking to have the plant in operation no later than April of 1918 and knowing that the canal ceased operations between November and February, Sanderson and Porter required all the equipment manufacturers to guarantee delivery by October 1917. [38]

Because the Chesapeake and Ohio Canal Company controlled the riparian rights at Dam 5, Sanderson and Porter was required to submit all construction plans to Canal Company General Manager G. L. Nicolson before construction could begin and, after the beginning of construction, to obtain the approval of the general manager prior to undertaking any work affecting the dam. [39]

CONSTRUCTION OF THE PLANT AT DAM 5

Aided by low water, construction began in June of 1917. Preparation of the site for construction, demolition of the existing stone and timber generating plant, and excavation for the foundation of the new building required the efforts of almost one hundred manual laborers, many using a pick and shovel. Stone taken from the walls of the mill building was crushed and stored for use as aggregate when mixing concrete. [40] Excavation for the forebay of the plant revealed the severely deteriorated condition of the West Virginia abutment and a "dangerous leak" in the foundation of the dam adjacent to the abutment. (Photographs HAER WV-28-6 through 10 illustrate the demolition and excavation work. Photograph HAER WV-28-11 illustrates the deteriorated West Virginia dam abutment and adjacent leak.) Much to the "horror" of the Canal Company's General Manager, workmen erected cofferdams, cut through the dam, removed loose stone, and filled the gap with concrete. [41]

Initially Sanderson and Porter's engineers had anticipated erecting a 300 foot long cofferdam upstream from the forebay excavation. After beginning the cofferdam construction, however, they unearthed a large volume of gravel-filled timber cribs originally built by the Canal Company to plug leaks that had plagued the dam. Removing these unanticipated obstacles to allow the proper unimpeded flow of water into the forebay necessitated expanding the cofferdam another 300 feet. [42] The engineers also found it necessary to deepen the excavation for the plant's foundation by ten feet so that the concrete foundation would be properly keyed into the bedrock. Removing the gravel-filled timber cribs, pouring concrete into and around the West Virginia abutment, and increasing the depth of the plant's foundation excavation greatly increased the difficulty of preparing the site for construction, delayed the start of power house construction until April 1918, and, consequently, increased the cost of the project. [43] The unanticipated repair, removal, and excavation work added approximately $20,000 to the original cost estimates for the Dam 5 plant. [44]

Because the actual construction of the plant did not begin until June 1917, two months after America's entry into World War I, manpower shortages and labor turnover as high as 500 percent per year ravaged the project during both 1917 and 1918. [45] The wartime draft was not the only event contributing to the inability of Sanderson and Porter to adequately staff the project. When the project was first conceived, both Potomac Light and Power and Sanderson and Porter had assumed that ample manual labor would be available, however, with construction having started in June, area farmers had largely absorbed the locally available supply of manual labor. To secure adequate manpower, Sanderson and Porter was forced to import workmen from New York and the deep South, raise the wages of manual laborers from 20 to 45 cents an hour and pay double time for all overtime and Sunday work, reduce the working day from 10 to 8 hours, and provide food and housing for the out of town workers and free daily transportation between Martinsburg and the plant for local workmen. [46] Securing skilled overhead high tension linemen was especially difficult and, consequently, the start of the transmission line between the Security and Dam 5 plants was delayed until late 1917. [47]

Unlike Dam 4, where on two occasions strikes interrupted construction, no labor disputes delayed work at Dam 5 and neither fatalities nor serious accidents marred the project. Very much like Dam 4, however, unusually severe weather conditions seriously impeded the progress of construction, especially during the winter of 1917 and the spring of 1918. During January and February 1918, workmen at Dam 5 repeatedly shoveled snow and cleared the access road to the dam to permit food and construction supplies to reach the site. [48] The Martinsburg World, looking back on the bitter winter, reported that at the Dam 5 site the repeated snowfalls had forced workmen there to clear the equivalent of 160 linear miles of road during that winter. [49] Despite record breaking low temperatures, work at the site slowed but did not come to a complete halt. Between 25 and 30 workmen continued to excavate and pour concrete, using steam heated sand and gravel and hot water to keep the concrete from freezing while it was being poured. [50]

The intense cold and heavy snowfall not only caused serious delays to construction, but also produced heavy spring floods all along the Potomac. Ice freshets in the spring of 1918 badly damaged the crest of Dam 5, and Potomac Light and Power asked the Canal Company contribute some of the $10,000 needed to repair the dam. Before the plant was completed, flood waters had spilled into the tailrace eight times and into the headworks three times (see HAER photo WV-28-14). Sanderson and Porter reported to the Board of Directors of Potomac Light and Power that an additional $26,000 in unanticipated extra costs was attributable to the exceptionally bad weather and the added labor costs resulting from the scarcity of skilled labor and the employment of "untrained men." [51]

With the crest of Dam 5 needing extensive repairs, Potomac Light and Power negotiated an agreement with the Canal Company permitting Sanderson and Porter to pour a completely new concrete cap six inches higher than the original one. With the use of two foot high flashboards, also permitted by the agreement, Potomac Light and Power could obtain a head of 18 feet 6 inches. [52]

Transporting generating equipment to the site was as difficult at Dam 5 as it had been a decade earlier at Dam 4. In April 1918 the electric generators arrived on railroad flat cars in Williamsport, Maryland. [53] Lacking a derrick at that site, the generators, each weighing almost eighteen tons, were manually rolled on pipes off the flatcars, over a timber ramp, and onto a Chesapeake and Ohio Canal barge. This difficult method of transferring the generators to the barges not only provoked heated debate between the workmen and foremen, but also resulted in the loss of the first generator off the side of the barge and into the canal. The following day a railroad crane was obtained from the Western Maryland Railway and the generator was retrieved from the canal and safely placed onto the middle of the canal barge. [54] Thereafter, a 14 horsepower gasoline powered launch towed the barge up the canal and across the Potomac above Dam 5. [55]

During July, with the power house's structural steel frame erected, roof trusses set, overhead crane installed, and brick walls half-completed, Coblentz could finally describe the work as progressing "splendidly." [56] During September workmen installed the turbines, generators, and switchboard (see photo HAER WV-28-27), and the following month electricians began connecting the generators to the switchboard, leaving only the exterior substation to be connected to the transmission lines (see photo HAER WV-28-28 and 30). Equipment testing and test operations began in November as the construction workforce, thinned by a virulent influenza epidemic and assualted by rain and high water, replaced all but 175 feet of the concrete cap on Dam 5 before the onset of winter forced a termination of activities. [57] With the line to Security completed first, Hagerstown received the first electricity generated by the Dam 5 plant in late November. Rain and bad weather also delayed the completion of the high tension transmission line between the Dam 5 and Martinsburg plants, and it was not until January 12, 1919, that electricity generated by the new hydroelectric plant surged into Martinsburg. [58]

The abnormally severe weather, acute labor shortages, extra excavation, unanticipated dam and abutment repair work, material and equipment price increases, and excessive material handling costs pushed the final cost of the Dam 5 plant to $464,570, $306,797 in excess of the original March 1917 estimate. [59] Table 9 gives power house construction specifications and final cost figures. Despite this extreme cost escalation, the Hagerstown and Frederick Railway continued lending Potomac Light and Power the funds needed to complete the project, confident that the plant's "cheaper power" would "very substantially increase" Potomac Light and Power's competitive position in Martinsburg and both companies future earnings. [60]

After visiting the plant in December, Coblentz expressed

TABLE 9

DAM 5 PLANT SPECIFICATIONS

Excavations:	
Power house and draft tubes	3,253 cu yds
Tailrace	5,733 cu yds
Headworks and abutment	5,151 cu yds
Forebay, trash racks, and river wall	10,013 cu yds
Total	24,150 cu yds
Concrete:	
Forebay bridge	121 cu yds
Power house and river walls	4,518 cu yds
Tailrace wall	292 cu yds
Head works and abutment	2,319 cu yds
Total	7,250 cu yds
Cofferdams (9 feet wide):	571 linear ft
Brick:	100.1 m
Structural steel:	35 tons
Dimensions:	
Headgates	798 sq ft
Power house finished floor and walkway area	5,560 sq ft
Power house interior space	235,560 cu ft
Window area	1,423 sq ft
Doors	198 sq ft
Slate roof	3,787 sq ft
Cost, (materials and labor combined):	
Power house, forebay, tailrace structures	$197,039.98
Turbines	62,306.13
Electric generating equipment	109,772.96
Substation equipment	11,045.74
Dam abutment and dam crest repairs	84,405.81
Total	464,570.62

Source: PEC, "Structures and Generating Station Equipment."

satisfaction at its operation, although he described the generators as "exceedingly noisy." [61] Plant operators reported minor problems with the Tirrel voltage regulators and recurring problems with the water wheel governors whenever the Dam 4 and Dam 5 plants operated in parallel. Potomac Light and Power also complained to the Leffel Compnay that the number one turbine was operating at 30 horsepower below its guaranteed output. [62] Adjustments to the tailrace brought the turbine up to capacity and Lombard concluded that the problem with the Dam 5 governors resulted from the different operating speeds of the governors used at the two hydroelectric plants. With the Dam 4 plant's governors requiring two and one-half seconds longer to adjust the water wheel gates to changes in load, parallel operation of the two hydroelectric plants would be difficult to maintain. To correct this problem, Lombard advised improving the speed of the Dam 4 governors by rebuilding and installing relay valves in them. [63]

THE OPERATION OF THE DAM 5 PLANT

The Dam 5 plant, like the plant at Dam 4, was a "run of the river" plant using only the water that would have otherwise flowed over the crest of the dam. Water impounded by Dam 5 entered an open forebay through four 22 feet wide concrete inlets located upstream of the existing stone abutment on the West Virginia side of the dam. Construction specifications called for the installation of four "Tainter" type headgates to control the flow of water into the forebay. Large steel-reinforced angular concrete piers, complete with bolts to accomodate the gates, were formed [64], however, neither the Tainter gates nor trash racks were ever installed at the inlet to the forebay (see HAER photo WV-28-21).

The upper forebay was approximately 80 feet wide and 110 feet long. A single sluice gate permitted the release of excess water back into the river before it reached the inlets to the open penstock. Water flowed out of the forebay and into a 55 by 48 foot rectangular open penstock, passing through a trio of 17 foot 6 inch wide trash racks, seen in HAER photo WV-28-49. Horizontal steel I-beams set into three foot thick concrete piers held vertical steel trash rack bars in place. [65]

Four timber "stop logs" or head gates controlled the flow of water from the open penstock into the two turbine scroll cases. [66] Each gate was built of 14 nine and one-half inch thick timbers held together by external steel straps and internal one inch diameter threaded steel rods, and capped by a large concrete slab. The gates hung on large chains from concrete beams cantilevered out from the north wall of the power plant building. An electric winch, mounted on a rail car riding tracks built atop the cantilevered concrete beams, was used to raise and lower these four gates. [67]

After passing beneath the stop logs, the water entered one of two steel-reinforced, poured concrete scroll cases. The scroll cases, tapering from a maximum radius of 16 feet to a minimum of eight feet, and a circular steel cone atop each turbine gate casing channeled water to the guide vanes smoothly and with a minimum of turbulence. [68]

Sanderson and Porter equipped the plant with two 51 inch diameter, Leffel, "Type Z," single-runner, vertical shaft turbines. Each turbine, operating under a head of 16 feet, developed 800 horsepower at 112.5 revolutions per minute at 85 percent of the gate opening. [69] Table 10 lists the operating efficiencies, horsepower, and discharge of water in cubic feet per second of each turbine under heads ranging from 16 to 19 feet. Operating under a reduced head because of the tailwater rising above its normal level reduced the output of each turbine as follows: [70]

Head	Revolutions Per Minute	Horsepower
15 feet	112.5	716
14	112.5	650
13	112.5	584
12	112.5	520
11	112.5	456

Using a nine inch diameter shaft capable of safely transmitting the 1,000 horsepower obtained with a 19 foot head, each turbine was direct-connected to a vertical shaft generator equipped with a roller thrust bearing designed to carry the full weight of generator rotor, flywheel, shaft, and turbine runner as well as a maximum of 65,000 pounds of thrust weight produced by the water flowing through the turbine. Each thrust bearing consisted of a large hexagonal nut screwed to the upper end of the extended turbine shaft with the nut resting on a flat circular steel plate surrounding the shaft. This steel plate was carried by roller bearings submerged in oil. Two guide bearings maintained the vertical alignment of the shaft. [71] A circular cast iron base ring, built across the top of the concrete draft tube, supported the turbine runners and shaft when they were disconnected from the generator and thrust bearing. Wedge shaped guide vanes, surrounding the wicket gate casing of each turbine, directed the flow of water to the 20 wicket gates. A steady bearing containing four fully submerged "lignum vitae" bearing blocks assured the constant alignment of the turbine shaft in the gate casing. [72] A ten foot nine inch diameter opening in both the basement and generator room floors permitted the installation and removal of

TABLE 10

OPERATING EFFICIENCY OF DAM 5 PLANT TURBINES

Head: 16 Feet Revolutions Per Minute: 112.5

Power	Horsepower	Efficiency	Discharge cfs
Full	800	81.6%	540
.95	760	88.1	476
.90	720	88.3	449
.80	640	85.8	411
.70	560	82	376
.60	480	77.6	341
.50	400	73.2	301

Head: 18 Feet Revolutions Per Minute: 112.5

Power	Horsepower	Efficiency	Discharge cfs
Full	930	80.7%	565
.95	883.5	87.2	497
.90	837	88.2	465
.80	744	86.8	420
.70	651	83.5	382
.60	558	79.3	345
.50	465	74.5	306

Head: 19 Feet Revolutions Per Minute: 112.5

Power	Horsepower	Efficiency	Discharge cfs
Full	990	80.1%	573
.95	940.5	86.8	504
.90	891	87.9	471
.80	792	86.8	423
.70	693	84	383
.60	594	79.6	346
.50	495	74.8	307

Source: PEC, "James Leffel & Company Dam No. 5 Water Wheel Contract."

the ten foot eight inch diameter turbine, and an extension to the turbine shaft, with a keyed and bolted coupling, allowed the circular cast iron generator base to sit 37 feet above the top of the turbine blades [73] (see HAER photo WV-28-62).

Directly beneath the generator room floor, an eight foot diameter, 10,000 pound, six-spoked, split and bolted cast iron flywheel was attached to each turbine-generator shaft. The flywheel, designed to produce 320,000 foot pounds of inertial momentum (WR^2), minimized the adverse effects of dramatic changes in load by absorbing and dampening abrupt changes in the rotational speed of the generator: [74]

Load Change	100%	50%	20%	10%
Speed Change	20%	12%	7%	1.5%

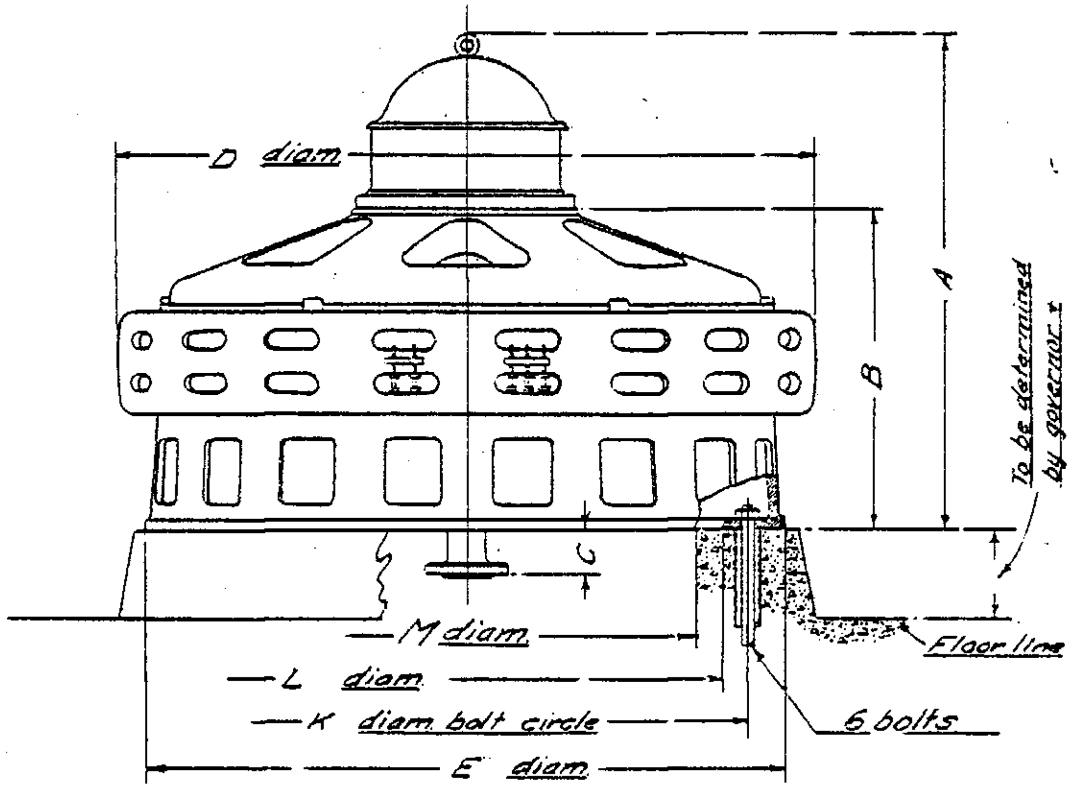
The two 700 kilowatt revolving field generators, (700 kVA at a power factor of one) both built by the Electric Machinery Manufacturing Company of Minneapolis, Minnesota, (serial numbers 503363 and 503887) each produced 2,300 volts of 60 cycle, 176 ampere, three-phase alternating current when operating at 112.5 revolutions per minute (see Figure 11). To supply the generators' 64 flat copper field coils, or poles, with direct current, each generator was equipped with a 50 kilowatt, 125 volt, 720 rpm Electric Machinery Company direct current exciter driven by a quarter-twist belt attached to the main generator shaft [75] (see HAER photos WV-28-52 through 55 for general views of the power house interior).

Sanderson and Porter chose to equip the Dam 5 plant with two Lombard Governor Company "Type T" 12,000 foot-pound capacity water wheel governors. Each governor was to be belt-connected to the turbine shaft just below the generator and equipped with electric speed control, permitting control of the governor from the switchboard (see HAER photo WV-28-59). Potomac Light and Power "preferred" that the Lombard "Type T" be installed at the Dam 5 plant because of the "familiarity" of the operators at Dam 4 with Lombard governors. [76] The Leffel Company had pushed for the installation of Woodward governors and when Leffel advised Sanderson and Porter that Lombard might not be able to deliver the governors by October 1917, Woodward type "HR" relay valve governors were substituted in the contract signed by Leffel and Potomac Light. [77] The "HR" governor was the Woodward Company's 12,000 foot-pound electric speed controlled model most closely matching the Lombard "Type T." Sanderson and Porter project manager George Waesche wrote to the Leffel Company that the:

> substitution of the Woodward governors was permitted with the definite understanding that we would write to the Lombard Company to see if delivery of the governors

FIGURE 11

GENERATOR DIMENSIONS, DAM 5 PLANT



ITEM	SIZE	K.V.A.	VOLTS	R.P.M.	PHASE	CYCLES
A	64T	700	2300	112½	3	60

DIMENSIONS AS GIVEN BELOW ARE APPROXIMATE AND NOT TO BE USED FOR CONSTRUCTION

ITEM	A	B	C	D	E	K	L	M
A	85	58	7	124	113½	106	101	99

Source: PEC: "Proposal: Electric Machinery Company Alternators."

> could be assured by the date of completion of the water wheels and if so that the Lombard governor would be furnished in accordance with the original proposal. [78]

The Lombard Company did in fact guarantee delivery by the required date and therefore allowed the Dam 5 plant to begin operations with Lombard governors and not be "inconvenienced by a later change." [79]

The six panel switchboard installed at the Dam 5 plant was designed and manufactured by the Electric Machinery Company and equipped exclusively with General Electric switches and instruments. Table 11 lists the components of the switchboard. The 2,300 low voltage current leaving the switchboard was elevated to 22,000 volt high tension transmission current by three 500 kVA single phase, oil insulated, self-cooling transformers mounted on a wooden pole structure (see photo HAER WV-28-30).

THE POWER PLANT BUILDING

The completed Dam 5 hydroelectric plant was a steel frame, brick walled structure set atop 24 inch thick concrete walls that formed the foundation and first story of the building. The initial Sanderson and Porter design called for the building to have a concrete foundation and dressed rubble stone walls like those of the Dam 4 plant, however, the final design substituted brick for stone. A twelve foot wide double swinging door on the south side of the building, the gable end adjacent to the West Virginia shore, afforded access to the plant's basement. The generator room floor, at elevation 140 feet above sea level, was eight inch thick concrete reinforced with one inch diameter steel rods. On the north, west, and east elevations, seventeen inch thick brick walls rose from the level of the generator room floor. The original plans also called for all four walls to be brick, but the need to install and remove the generating equipment dictated the use of easily dismantled wooden siding on the south side of the building. [80]

Large six foot wide and twelve foot high windows allowed natural illumination into the plant, and a series of six foot wide and three and a half foot high windows just below the roof allowed heat produced by the generators to be vented from the building. Steel roof trusses set twenty-one feet above the generating room floor carried a wire mesh (Hy-Rib) reinforced, four inch thick, concrete roof slab covered with a layer of slate shingles. Two forty-eight inch diameter ventilators, mounted atop the ridge of the roof, provided additional ventilation. Rails, set atop the side walls of the building thirteen feet and six inches above the generating room floor carried a fifteen ton, chain operated

TABLE 11

DAM 5 PLANT SWITCHBOARD COMPONENTS

Panel 1: Double circuit exciter panel (125 volt):
2 direct current amperemeters
1 direct current voltmeter with 175 volt scale
2 4-point receptacle with plug
2 Triple pole, single throw lever switches, 400 ampere capacity
2 rheostat mountings with hand wheels
1 equalizer rheostat with hand wheel.

Panel 2: Tirrel regulator panel:
1 Tirril regulator with a potential transformer.

Panel 3: Generator panel number 1:
1 alternating current amperemeter, 300 ampere scale
1 3-way amperemeter switch
1 polyphase indicating wattmeter, 1,200 kilowatt scale
1 power factor indicator
1 field amperemeter
1 synchronous receptacle with plug
1 8-point receptacle with 4-point plug
1 field switch
1 triple pole, single throw, non-automatic oil switch with hand operating mechanism (remote)
2 current transformers
2 potential transformers
1 watt-hour meter
1 rheostat mounting with hand wheel, chain and sprocket wheel
3 single pole, single throw, 2,300 volt, 300 ampere disconnecting switches.

Panel 4: Generator panel number 2:
Duplicate of Panel 3.

Panel 5: Low tension transformer panel:
1 polyphase indicating wattmeter
1 triple pole, single throw, automatic oil switch with hand operating mechanism (remote)
2 current transformers
2 potential transformers

3 single pole, single throw, 2,300 volt, 600 ampere disconnecting switches
1 inverse time limit relay
1 D3 Integrating watt-hour meter.

Panel 6: Outgoing feeder and station auxiliaries panel:
2 alternating current amperemeters
1 automatic oil switch with hand operating mechanism for 2,300 volt outgoing feeer
1 automatic oil switch for station auxiliary circuit
9 disconnecting switches
4 current transformers
2 inverse time limit relays
1 D3 integrating watt-hour meter on outgoing feeder.

Swinging Panel:
1 synchroscope
1 frequency meter
1 station voltmeter
1 alternating current voltmeter

Other Station Equipment:
1 set copper bus bars, connections, and switch
3 2,300 volt, multigap lightning arrrester
1 33,000 volt electrolitic lightning arrester with 22,000 volt cones
3 choke coils, 2,300 volts, 200 ampere capacity.

Source: "Electric Machinery Company Proposal, Dam No. 5 Electrical Equipment" and "Proposal: Electric Machinery Company Alternators."

Whiting overhead crane that enabled each generator and turbine to be lifted out for maintenance and repair. [81]

COMPARISON OF THE PLANTS AT DAMS 4 AND 5

The Dam 5 plant's 1,600 horsepower was a mere two-hundredths of one percent of the estimated 1,058,000 horsepower of hydroelectric capacity installed in the United States during 1917. Despite its small size the plant was among the 90 percent of low head plants built with single-runner vertical shaft turbines direct connected to vertical shaft generators equipped with thrust bearings. [82]

The vertical shaft turbine and direct connected "umbrella" type generator was available in 1906 as the Dam 4 plant was being planned. Limited commercial availability and the lack of standardization, inadequate thrust bearings, and the low rotational speeds of single-runner vertical turbines made the tandem, multi-runner horizontal turbines preferable even when shafts and bevel gears or rope drive were needed to transmit the mechanical power of the turbine to the generator. [83] By 1914 significant increases in speed and output had resulted in the "rapid passing away...of the multi-runner turbines" and the "general adoption of single-runner vertical shaft turbines." [84] H. B. Taylor, describing some of the prominent low head plants built in 1914 asserted that had these plants been built five years earlier, "it would have been impossible to install vertical shaft single-runner units of the same capacity." [85] He continued:

> ...for a given head and speed it is now possible to secure from a runner a greater output than was possible two or three years ago, or, conversely, for a given head and capacity it is possible to operate the more recently designed runners at a much higher rotational speed than was the case...a few years ago. [86]

The Northern Virginia Power Company installed its first single-runner vertical shaft turbine in its Millville plant in 1914 and attributed most of the company's record 1914 profits to the "great efficiency shown by the new type of vertical wheel." [87] The company proudly reported that with the same amount of water, the vertical wheel developed almost twice as much horsepower as did the original horizontal wheel installed in 1905. [88] By 1918, Northern Virginia Power's chief engineer labeled his company's remaining multi-runner horizontal shaft turbines and rope driven generators "obsolete at this time." [89]

Crucial to the effective utilization of the vertical turbine was the devlopment of a reliable generator-mounted bearing capable of carrying, with a minimum of friction, the massive weight of the turbine and the downward thrust of the water flowing through the runners. As the speed and horsepower of vertical turbines was increased and bearing friction was reduced, the primary advantages of multi-runner horizontal turbines faded in comparison to the advantages of vertical turbines. The single-runner turbines installed at Dam 5 avoided the primary disadvantages of the tandem, multi-runner horizontal turbines installed at Dam 4: the need for more than one wicket gate and gate operating mechanism and the difficulty of obtaining "equal gate openings;" the efficiency losses resulting from the discharge of two runners into a common draft tube; and differences in head between the first and last runners on a line of horizontal turbines. [90]

More compact than a multi-runner horizontal turbine, the vertical turbine also possessed fewer parts, was more accessible for repairs, and generally less expensive to install and maintain. With the use of an extension shaft, a generator attached to a vertical shaft turbine could easily be elevated out of the reach of floods. [91]

The Dam 5 plant also utilized improvements designed to reduce the inefficiencies of delivering water to and discharging water from the turbines. The plant's molded concrete scroll case delivered water at maximum velocity uniformly across the circumference of the runner casing, minimized friction, and reduced the turbulance and air intake common to horizontal turbines in open penstocks. The curved concrete draft tubes permitted greater conversion of head velocity into useful head by appreciably reducing the eddies, whirls, and abrupt turns and changes in direction found in even the most efficiently installed center discharge horizontal turbines. [92]

The increased speed and output of the vertical turbines was matched by the development of economical and efficient direct connected generators operating at speeds well below 360 rpm. The use of a direct connected generator operating at the same speed as the vertical shaft turbine avoided the need for speed increasing gears or rope drive.

A brief comparison of the output of the two plants reveals the significance of the hydraulic and electrical advances made between 1909 and 1918. With the same head and discharge rate, any one of the Dam 5 plant's single-runner vertical shaft turbines produced five percent more horsepower than any one of the Dam 4 plant's four runner horizontal shaft turbines. With the Dam 5 plant's turbines connected directly to the generator, they could deliver as much as 15 percent more power to the generators than could the horizontal turbines at Dam 4. Likewise, the generators at Dam 5, operating at one-third the speed of those at Dam 4, had a capacity 40 percent greater.

FOOTNOTES: CHAPTER V

[1] PL&PC Minutes, August 7, 1916; Certificate of Incorporation, "West Virginia Stockholders Minutes," August 16, 1916.

[2] WVPSC, Annual Report, pp. 92-94.

[3] Martinsburg World, August 17, 1916; Martinsburg Evening Journal, August 16, August 17, 1916; newspaper articles dated August 19 and September 26, 1916, MPC Scrapbook, PEC.

[4] WVPSC, Fourth Annual Report, p. 722; PL&PC Minutes, August 18, 1916; Martinsburg World, August 19, 1916; Martinsburg Evening Journal, August 19, 1916.

[5] H&F Minutes, September 1, September 20, 1916; PEC Historical File: H&F, January 1, 1917.

[6] H&F Minutes, September 20, 1916.

[7] Martinsburg Evening Journal, October 13, 1916; newspaper articles dated September 30, October 6, October 10, October 31, November 6, 1916, MPC Scrapbook, PEC.

[8] NVPC Minutes, September 14, September 19, 1916; PL&PC West Virginia Stockholders Minutes, January 30, 1917; PL&PC Minutes, January 22, 1917; WVPSC, Fouth Annual Report, p. 305; Martinsburg World, January 29, 1917; Martinsburg Evening Journal, January 29, 1917.

[9] D.M. Swink to L.F. Cooper, NVPC Minutes, February 21, 1917.

[10] NVPC Minutes, March 20, April 17, 1917; "Legal Notice" dated April 21, 1917 MPC Scrapbook, PEC; Martinsburg World, May 22, 1917.

[11] Martinsburg World, May 3, May 4, May 9, 1917.

[12] Martinsburg World, May 5, May 8, May 10, May 14, 1917.

[13] Martinsburg World, June 13, August 4, August 7, September 2, 1917; Martinsburg Evening Journal, June 6, June 13, June 14, 1917; Martinsburg Journal, September 7, 1917; Articles dated May 19, May 23, August 21, 1917 and article titled "Power Co. Accepts Local Franchise" in MPC Scrapbook, PEC; PEC Historical File: NVPC, September 18, 1917.

[14] NVPC Minutes, July 30, 1914, July 20, 1915, July 18, 1916,

July 30, 1916; WVPSC, Fourth Annual Report, p. 94; WVPSC, Annual Report: 1916-1917, p. 412; "Structures and Generating Station Equipment," p. 153, PEC.

[15] PL&PC WV Stockholders Minutes, January 29, 1918.

[16] Ibid.

[17] Monthly averages computed from data contained in the reports of the General Manager to the Executive Committee of the Hagerstown and Frederick Railway Company Board of Directors, H&F Minutes, January 10, January 27, March 13, April 1, April 19, July 21, October 19, November 9, 1916. Other references to expansion are found in H&F Minutes, September 2, October 10, December 6, 1915 and H&F Annual Report December 31, 1915.

[18] H&F Minutes, March 13, November 11, 1916.

[19] H&F Minutes, November 11, 1916.

[20] Ibid.; Martinsburg World, January 18, 1917; newspaper article dated November 25, 1916, MPC Scrapbook, PEC.

[21] H&F Minutes, February 14, March 13, October 19, November 11, 1916, April 19, August 28, 1917.

[22] Martinsburg World, May 22, 1917; H&F Minutes, January 18, March 6, August 28, 1917.

[23] H&F Minutes, March 6, August 28, 1917.

[24] Ibid.

[25] Ibid.

[26] PL&PC Minutes, January 15, 1917

[27] Water Power Chronicle, 2 (July 1913):3; newspaper article dated August 19, 1916, MPC Scrapbook, PEC.

[28] Newspaper articles dated November 25, December 23, 1916, MPC Scrapbook, PEC.; PL&PC West Virginia Stockholders Minutes, January 30, 1917, PEC; PL&PC Minutes, January 5, 1917.

[29] J.S. Wessel to E. L. Coblentz, PL&PC Minutes, March 13, 1917.

[30] Ibid.

[31] Ibid.

[32] Ibid.

[33] Ibid.

[34] Ibid.; PL&PC Minutes, December 3, 1917.

[35] Ibid.

[36] "Sketch Design for Superstructure, Dam 5 Plant," PEC Minor Stations; Martinsburg World, June 1, 1917; S&P to Leffel, June 2, 1917, Leffel File AB-9592.

[37] Ibid.

[38] S&P to Lombard, April 25, 1917, S&P to Leffel, May 14, 1917, Leffel File AB-9592; PL&PC to G.L. Nicolson, October 8, 1917, March 30, 1918, C&O Papers, NA; "Structures and Generating Station Equipment," p. 339, PEC.

[39] S&P to G.L. Nicolson, October 2, 1917, C&O Papers, NA.

[40] "S&P Progress Report, October 1, 1918," collection of Charles Morrison, Hagerstown, Md.; Martinsburg World, April 5, 1918.

[41] PL&PC Minutes, September 22, December 3, 1917; S&P to PEC, October 20, 1933, Dam 5 File, PEC Minor Stations.

[42] Ibid.; PL&PC Minutes, December 3, 1917, May 6, 1918.

[43] Ibid.; "S&P Progress Report, October 1, 1918," Charles Morrison, Hagerstown, Md.

[44] Ibid.; PL&PC Minutes September 22, December 22, 1917; S&P to PEC, October 20, 1933, Dam 5 File, PEC Minor Stations.

[45] Martinsburg World, June 1, 1917; "Structures and Generating Station Equipment," PEC.

[46] "Structures and Generating Station Equipment," p. 331; PL&PC Annual Report, January 28, 1919; Advertisements for workmen appeared daily in the Martinsburg World from September 17 to October 1, 1918. Advertsiments for bricklayers appeared in the Martinsburg World during July 1918; H&F Minutes, August 28, 1917; PL&PC Minutes, May 6, 1918, January 28, 1919.

[47] PL&PC Minutes, December 3, 1917.

[48] H&F Annual Report December 31, 1918; PL&PC Annual Report, Year ending December 31, 1918; Interview, Robert L. Saunders, Pikeside, W.V., August 5, 1980; PL&PC Minutes, May 6, 1918,

January 28, 1919; H&F Minutes, August 28, 1917.

[49] Martinsburg World, April 5, 1918; "Structures and Generating Station Equipment," p. 329.

[50] Martinsburg World, April 5, 1918; H&F Minutes, January 7, 1918.

[51] S&P to G.L.Nicolson, April 26 and May 24, 1918, G.L. Nicolson to H.R. Preston, July 2. 1918, C&O Papers, NA; PL&PC Minutes, May 6, 1918; PL&PC Annual Report, December 31, 1918; "Structures and Generating Station Equipment," p. 329, PEC.

[52] Agreement, August 8, 1918, "Potomac Development Volume 1," PEC; S&P to G.L. Nicolson, April 26, 1918, C&O Papers, NA.

[53] S&P to Leffel, May 14, 1917, Leffel File AB-9592.

[54] Interview with Robert L. Saunders, Pikeside, W.V., August 5, 1980.

[55] S&P letter, May 14, 1917; PL&PC to G.L. Nicolson, August 9, 1917, C&O Papers, NA.

[56] H&F Minutes, July 29, August 9, September 12, 1918; "Progress Report, October 1, 1918," Charles Morrison, Hagerstown, Md.

[57] H&F Minutes, November 4, December 5, December 27, 1918; H&F Annual Report, December 31, 1918; S&P to G.L. Nicolson, September 18, 1918, C&O Papers, NA; PL&PC, WV Stockholders Records, January 28, 1919.

[58] H&F Minutes, December 5, December 27, 1918, January 16, 1919; PL&PC Annual Meeting, January 28, 1919; "S&P Progress Report," Charles Morrison, Hagerstown, Md.; Martinsburg World, January 15, 1919.

[59] H&F Minutes, April 28, 1918; H&F Annual Report, December 31, 1918; "Structures and Generating Station Equipment," p. , PEC.

[60] H&F Minutes, July 29, 1918.

[61] H&F Minutes, December 5, 1918.

[62] S&P to Leffel, February 19, 1919, Leffel File AB-9592.

[63] Lombard to S&P, March 20, April 10, April 15, 1919, Leffel File AB-9592.

[64] Drawing 204-B-16, PEC Minor Stations.

[65] Drawings 204-B-16, 204-B-11, PEC Minor Stations.

[66] Drawing 204-C-7, PEC Minor Stations.

[67] Drawings 204-B-9, 204-B-10, 204-B-20, PEC Minor Stations.

[68] Drawing 204-B-2, PEC Minor Stations.

[69] Drawings 24925, 25065 PEC Minor Stations; Leffel to S&P, February 27, 1919, Leffel File, AB-9592; "James Leffel & Co. Dam No. 5 Water Wheel Contract," March 30, 1917, PEC Minor Stations.

[70] Ibid.

[71] Drawings 36584, PEC Minor Stations, Electric Machinery Manufacturing Co. Proposal; Leffel to PEC, July 7, 1936, Leffel to EM, July 24, 1936, Leffel File AB-9592.

[72] Drawings 32448, 36584, "James Leffel and Company Dam 5 Contract," PEC Minor Stations.

[73] Ibid.; Drawings 25065, 25066, PEC Minor Stations; Leffel to EM, May 12 and May 17, 1917, Leffel File AB-9592.

[74] Drawing 6234, Electric Machinery Manufacturing Co. Proposal, PEC Minor Stations.

[75] Electric Machinery Manufacturing Company, "Electrical Equipment Test Log."

[76] S&P to Lombard Governor Co., April 25, 1917, Leffel to Woodward Governor Co., May 18, 1917, Leffel File AB-9592.

[77] Ibid.

[78] S&P to Leffel, April 30, 1917, Leffel File AB-9592.

[79] Ibid.; Lombard to S&P, April 26, 1917, Leffel File AB-9592.

[80] Drawings 204-B-13, 204-B-14, PEC Minor Stations.

[81] Drawings 204-A-4, 204-C-6, 204-A-1, 204-B-4, PEC Minor Stations.

[82] National Electric Lighting Association, _Proceedings of the 1918 Anual Meeting_, June 14, 1918, p. 278; Rushmore and Lof, _Hydro-Electric Power Stations_, pp. 226, 229; National Electric Lighting Association, _Proceedings of the 1917 Annual Meeting: Technical and Hydro-Electric_, May 9, 1917, pp. 141, 142.

[83] Lyndon, *Development and Electrical Distribution of Water Power*, p. 63; Mead, *Water Power Engineering* (1908), p. 504; Mead, *Water Power Engineering* (1920), p. 516; von Schon, *Hydro-Electric Practice*, pp. 258, 301.

[84] Taylor, "Hydraulic Turbines," p. 269; Taylor, "Present Practice in the Design and Construction of Hydraulic Turbines," pp. 129, 137.

[85] Taylor, "Hydraulic Turbines," pp. 272-273; Taylor, "Present Practice in the Design and Construction of Hydraulic Turbines," p. 137.

[86] Ibid.

[87] NVPC Minutes, July 20, 1914.

[88] Ibid.

[89] D.M. Swink to L.F. Cooper, NVPC Minutes, April 1918.

[90] National Electric Lighting Association, *Proceedings of the 1913 Annual Meeting: Technical and Hydro-Electric*, p. 169.; Rushmore and Lof, *Hydro-Electric Power Stations*, pp. 324-325; Taylor, "Hydraulic Turbines," p. 273; Creager and Justin, *Hydro-Electric Handbook*, p. 593; "Hydro-Electric Systems," *Power* 37 (June 24, 1913), p. 894.

[91] National Electric Lighting Association, *Proceedings of the 1917 Annual Meeting*, pp. 142, 149; Taylor, "Present Practice in the Design and Construction of Hydraulic Turbines," p. 149; Mead, *Water Power Engineering* (1920), p. 509; Creager and Justin, *Hydro-Electric Handbook*, p. 599; Rushmore and Lof, *Hydro-Electric Power*, pp. 227, 324-325.

[92] Ibid., p. 238-240; Taylor, "Hydraulic Turbines," pp. 270-271, 273; "Tendencies of Electrical Development in 1916," *Electrical World* 69 (January 13, 1917), pp. 74-75.

CHAPTER VI

THE EMERGENCE OF THE POTOMAC EDISON COMPANY

THE ORIGINS OF A REGIONAL ELECTRIC UTILITY

At the January 28, 1919 annual meeting of the Potomac Light and Power Company, Emory L. Coblentz assessed the preceeding year and concluded:

> The year 1918 has been one of the most difficult and unsatisfactory, from the standpoint of operations, of any year in the history of the public utility business. With the cost of materials and labor and everything which is employed in the generation of electric current rising by leaps and bounds, it has been a constant effort upon the part of the management to maintain the credit of the company and pay its fixed charges. [1]

The completion of the Dam 5 plant, the West Virginia Public Service Commission's decision to permit Potomac Light to increase its electric rates as of December 1, 1918, the addition of new customers, and the sale of "surplus current" to the Hagerstown and Frederick Railway Company led Coblentz to "look forward" to "very much better results in the year 1919 than the year just past." [2]

The year 1919 was, in fact, significantly better for both Potomac Light and Power and the Hagerstown and Frederick Railway. Potomac Light closed down the aging Martinsburg steam generating plant in January and, with the Dam 5 hydroelectric plant in operation, Coblentz proudly reported: "we are now getting the benefit of the large capital expenditures which we have been making." [3] With the sale of electricity generated at the Dam 5 plant, Potomac Light's annual gross earnings rose from $95,287 to $203,044 and, while operating expenses doubled, the company's balance sheet showed net earnings of $35,364 replacing 1918's deficit of $3,493. [4] Likewise, because of the improved operating efficiency resulting from the use of the Dam 5 plant, the Hagerstown and Frederick's 1919 net earnings climbed to $95,919. [5] In addition to closing the Martinsburg plant of Potomac Light, the added generating capacity supplied by the Dam 5 plant permitted the Hagerstown and Frederick to close its antiquated Waynesboro, Pennsylvania coal fired electric generating station and shut the Security plant between 12 and 6 AM, allowing the Dam 4 and 5 plants to carry the full load during these hours. [6]

The mid-1919 absorption of the Northern Virginia Power Company into the Hagerstown and Frederick network also contributed to the financial gains made by Potomac Light and Power. At the beginning of 1919, Northern Virginia Power Company's Superintendent D. M. Swink advised company President Lewis F. Cooper that the utility faced "more serious problems than at any time heretofore." [7] High labor turnover and severe shortages of electrical equipment, both of which were incurred as a result of World War I, as well as difficulties in obtaining rate increases from three states, Maryland, Virginia, and West Virginia, and potentially disruptive competition with other utilities left Northern Virginia Power unable to "render the most satisfactory service." [8] Swink concluded:

> In order to take care of the competitive conditions and available power demands in this territory, it is imperative that a large amount of new work be gotten into operation at the earliest possible moment...[9]

"To procrastinate," Swink warned President Cooper, "will mean the most serious injury to your company." [10]

Swink's dire message was amplified by Cooper during a special meeting of stockholders convened to discuss the need for and the financing of a 5,000 kilowatt expansion of the company's Millville generating station. Cooper asserted that "unfortunate, unexpected, and largely unavoidable conditions...suddenly forced upon us by the World War created the conditions that changed our well balanced day and night load into an overloaded day load." [11] With both primary and auxiliary generators in constant use and with spare parts difficult to obtain, the company was prevented from shutting down equipment for preventive maintenance or much needed repairs, and the result was equipment failure and frequent interruptions in service. With the company's construction and improvement bonds being marketed in competition with United States government Liberty Bonds and with rate increases granted in Maryland and West Virginia but not Virginia, the Board of Directors was forced to withhold stock dividends and raise the balance of the needed construction funds by assessing stockholders a total of $51,000 in exchange for the remaining unsold bonds. [12]

Faced with such serious financial uncertainty and operating difficulties and with the West Virginia Public Service Commission pressuring both Northern Virginia Power and Potomac Light and Power to cease their "competitive warfare" and interconnect their generating plants, the May 1919 offer of Hagerstown and Frederick President Emory Coblentz to purchase the stock of the Northern Virginia Power Company at $140 per share was favorably received by all but two stockholders. [13]

Coblentz, immediately assuming the presidency of Northern Virginia Power, publicly acknowledged that the acquisition was designed primarily to eliminate competition, but asserted that the consolidation of operations and the elimination of competition would assure more economical operations and "efficient service." [14] In Martinsburg, Potomac Light and Power leased the lines and property of the Northern Virginia Power Company for $150 per month and connected its lines to those of Northern Virginia. This interconnection permitted the abandonment of the small and aging Berkeley Springs, West Virginia, coal fired electric generating plant. [15] The amalgamation of the Northern Virginia Power Company with Potomac Light and Power and the Hagerstown and Frederick Railway created a system operating four steam turbine and four hydroelectric plants with a combined generating capacity of 30,000 kW. The system was linked together by 430 miles of high tension transmission lines stretched across four states, Virginia, West Virginia, Maryland, and Pennsylvania. The total output of the system's eight plants during 1919 was 46,628,000 kWh, of which 42.7 percent, 19,918,000 kWh, was hydroelectricity and 26,710,000, 57.3 percent, was generated by steam turbines. [16]

The timing of the acquisition proved to be exceptionally fortuitous for Potomac Light and Power because one week after the absorption of Northern Virginia Power into the Hagerstown and Frederick network a fire totally destroyed all three of the Dam 4 plant's high tension transformers (see photo HAER WV-27-30). Potomac Light and Power was able to avoid a prolonged shut down of the plant by quickly obtaining replacement transformers from the Millville generating plant. Transformer failures also periodically crippled the Martinsburg and Dam 5 generating plants during 1920. [17]

To meet the increasing demands being placed upon the system by a 40 percent growth in electric demand in the Northern Virginia Power territory, the Hagerstown and Frederick's Board of Directors approved the installation of a 750 horsepower boiler and a 6,250 kVA (5,000 kW) Westinghouse Electric steam turbine-generator at the Millville generating plant. With the expanded generating capacity, larger and more complicated equipment, and complex intercompany operations, the Hagerstown and Frederick also appointed a Power Superintendent and Load Dispatcher to supervise the generation and distribution of the 56,966,000 kilowatt hours of electricity produced during 1920 by the three companies' eight interconnected steam and hydroelectric plants. [18] Of the total annual kilowatt hours produced, 22,896,000 kWh (40 percent) was generated by the four hydro plants and the other 34,070,000 kWh was generated by the coal fired steam turbine plants. [19]

As in 1917, the price and availability of coal was "extremely unsatisfactory" during 1920. [20] At the 1921 annual meeting, Coblentz informed stockholders that because of a drop in coal shipments, "it was at times only with the greatest difficulty that a sufficient supply of fuel could be obtained to keep our plants in continuous operation." [21] When forced to buy coal on the open market, the Hagerstown and Frederick was forced to pay as much as $7 per ton above the contract price. Open market coal prices increased from $5.73 a delivered ton in January to $10.02 a ton by August and declined a mere $1.22 to $8.80 a ton at the end of 1920. [22] The increased coal costs forced the company to raise its electric as well as its gas and railway rates. Coblentz reported that the rate increases were insufficient to cover the escalating fuel bills and "it was only because of the large supply of power from water and coordination of the several steam plants..." that the combined earnings of the Hagerstown and Frederick and its two subsidiary companies increased from $229,101 in 1919 to $276,891 in 1920. [23] Coblentz, noting that electric revenues had accounted for only 25.2 percent of system income in 1915 and 65.3 percent of system revenues in 1920, concluded: "The trend is still toward deriving a greater percent of revenues from the sale of energy." [24]

Potomac Light, although mothballing the generating equipment at the Martinsburg plant, continued to use that station's switchboard. The growing load being distributed through it, however, made the equipment "obsolete, inadequate, and dangerous," and the installation of a new switchboard was soon required. The firey destruction of part of the old Martinsburg switchboard just as the new equipment was arriving demonstrated, in President Coblentz's words, the "wisdom of making this improvement." [25]

During 1921, the anemic condition of the coal, glass sand, limestone, and textile industries and the failure of the West Virginia apple crop depressed demand for electricity in the Pennsylvania, Maryland, and West Virginia areas surved by Potomac Light and the Hagerstown and Frederick. [26] Despite an increase in the total number of customers across the three company system from 13,128 in 1920 to 15,570 in 1921, total system electric output declined to 56,278,000 kilowatt hours, a decrease of 688,000 kilowatt hours from 1920. Of the total output, hydro plants generated 41 percent and coal burning steam electric plants contributed 59 percent. Seeking to increase the output of the Dam 4 plant, Potomac Light repaired the crest of the Dam and finally installed flash boards. The water usage fee at both Dams 4 and 5 was also increased to $750 per plant per year. [27]

The Hagerstown and Frederick Railway Company strengthened its hold on the Northern Virginia Power Company by acquiring all the outstanding stock and, in order "to give stability of operation" and provide the "proper coordination in the management and development" of the two companies south of the Potomac River, transferred control of all Potomac Light and Power Company stock to the now fully owned subsidiary, Northern Virginia Power. [28] In the Hagerstown and Frederick's 1921 Annual Report, President Coblentz, no doubt responding to public criticism arising from the unification of the Potomac Light and Northern Virginia properties, asserted:

> By reason of ownership of all of the common stock of the Potomac Light and Power Company by the Northern Virginia Company, your management is enabled to operate these two properties practically as one, which not only is in the interest of economical and efficient management, but also avoids duplication and in the end gives very much better service to the public.
>
> All these subsidiaries are operated as a part of your system, and we believe all the communities served by them are willing to go upon record that our acquisition of these properties has been in their interest, for the reason that the companies connected with the system are able to furnish an adequate supply of electric energy suitable to the needs of the various communities such as could not have been done with separate operating companies. [29]

THE POTOMAC PUBLIC SERVICE COMPANY

In 1922, having acquired almost 100 percent of the stock of both the Potomac Light and Power and Northern Virginia Power companies, and with electricity sales supplying 77 percent of the income of the Hagerstown and Frederick Railway Company, the system was renamed the Potomac Public Service Company. [30] The Potomac Public Service Company, with a majority of its stock controlled by the American Water Works and Electric Company, functioned as a holding company responsible for coordinating the operations of the subsidiary companies, all of whom retained their individual identities. Unable to expand the Security generating station any further, forecasting a significant growth in electric demand, and seeing coal prices drop by almost 50 percent (from $10.02 a ton in 1920 to 5.16 a ton by March 1922), the utility announced plans to construct a 15,000 kW coal-fired steam turbine electric generating plant at Williamsport, Maryland. [31] Williamsport was chosen because it was the geographic center of the territory served by Potomac Public Service and because the adjacent Potomac River could supply the large volume of water needed by the plant's steam turbine condensers. Additionally, the plant was adjacent to both the Chesapeake and Ohio Canal and the Western Maryland Railway, both of which could deliver construction materials and, once the plant was in operation, coal. [32]

Ironically, the construction of the Williamsport plant had a temporarily detrimental effect upon the operation of both the Dam 4 and 5 plants, and indirectly contributed to the need to reopen and operate the antiquated Martinsburg generating station. In

May, Potomac Light's Vice-President reported that the Martinsburg station was being made operational for "standby service during low water season," [33] and in the event that other plants temporarily went out of service. The impetus for this decision was the loss of the Dam 5 plant for more than eight days when a turbine shaft cracked. By July, new oil switches had been installed at the Martinsburg substation and the generating equipment at the plant was repaired, tested, and available for emergency operations. [34] The renovation of the plant proved to be an extremely wise decision because during the summer of 1922 the exceedingly low flow of the Potomac caused hydroelectric generation to plummet to its lowest level in many years. [35]

The use of the Chesapeake and Ohio Canal to transport construction materials to the Williamsport plant site required drawing water from the Potomac at both Dams 4 and 5 and this diversion of water reduced even further the volume of water available for use by the two hydro plants, frequently forcing the plants to cease operating. During November 1922, for example, the Dam 4 and 5 plants generated only eight percent of the electricity the two plants had generated during November of the preceeding year, producing only four percent of the Potomac Public Service Company's monthly system output. The October and November output of the two hydro plants was the lowest output in the history of either plant. Potomac Light was not only forced to continuously operate the Martinsburg generating station, but also import large volumes of current from the Millville, Virginia and Security, Maryland stations. Both actions had seriously detrimental effects on Potomac Light's operating efficiency and finances. The one consolation arising from the exceptionally small use of the two hydro plants was the opportunity that the lull in their operation gave the electric company's maintenance department to restore the plants to "first class condition for future operation." Repairs included replacing decayed and badly leaking timbers in the headgates of the Dam 4 plant's third, unused open penstock, installing static absorbers on the bus bars at both plants, and, at the Dam 5 plant, installing three new roof ventilators and rewinding both generators. [36]

OPERATIONS AFTER THE COMPLETION OF THE WILLIAMSPORT PLANT

The operation of the Williamsport generating plant caused a number of significant changes across the Potomac Public Service Company system. At the end of 1923, the name of the holding company was changed to the Potomac Edison Company; operational and financial control of the subsidiary companies was tightened, and their separate identities discarded. The Martinsburg generating plant, in operation since 1890, was permanently abandoned [37] and the importance of the generating plants at Dams 4 and 5 began diminishing. Before the completion of the Williamsport plant, the plants at Dam 4 and 5 represented 9.3 percent of Potomac Edison's installed generating capacity. After the opening of the Williamsport plant, the 2,400 kilowatt capacity of the two hydroelectric plants represented only 4.7 percent of Potomac Edison's 50,750 kW generating capacity. Table 12 displays Potomac Edison's 1924 and 1925 system output and compares the percentage supplied by steam turbine and hydroelectric plants. Figure 12 vividly illustrates the declining importance of hydroelectricity after the construction of the Williamsport plant.

The completion of the Williamsport generating plant also prompted Potomac Edison to upgrade the system's switchboards, substations, and high tension transmission lines. Between 1923 and 1927 all of Potomac Edison's 22,000 volt high tension lines were converted to carry 33,000 volts, the switchboards at the Security, Martinsburg, and Dam 4 plants were upgraded, and new 33,000 volt outdoor substations equipped with automatic oil switches were erected at Martinsburg and Dam 5. (The three bay, steel frame 33,000 volt substation erected in 1925 at Dam 5 appears in photograph HAER WV-28-42.) Among the first two lines converted from 22,000 to 33,000 volts were the lines between Williamsport and Martinsburg, and Hagerstown and Security. The "southern end" of the Potomac Edison system, the former Northern Virginia Power Company territory, was not upgraded until 1926. All of the 22,000 volt transmission lines were converted when the Dam 4 to Martinsburg line was finally replaced and 33,000 volt transformers were installed at the Dam 4 plant substation in 1927 (see photos HAER WV-27-31 and 32). [38]

With the Williamsport plant in operation and the conversion of the high tension transmission lines from 22,000 to 33,000 volts in progress, Potomac Edison's managers and plant operators concerned themselves primarily with routine maintenance and the infrequent and unpredictable operational problems and disasters. A flood in 1924, for example, raised the Potomac River to record breaking levels and not only swept away the flashboards and lowered the output of both plants, but also damaged the financially ailing Chesapeake and Ohio Canal so badly that all operations on the waterway were permanently terminated. At the Dam 4 plant, both the forebay and penstock headgates sustained damage requiring repairs and the tailrace at the Dam 5 plant had to be dredged. [39] The cessation of operations on the C&O Canal did significantly increase both the hydroelectric output and income of Potomac Edison by allowing the company to use all the water flowing in the Potomac. [40]

The most destructive accident at the Dam 5 plant occurred in 1925 when the number one turbine was so seriously damaged that it had to removed from the plant, returned to the factory, and almost completely rebuilt. An employee painting the newly erected 33,000

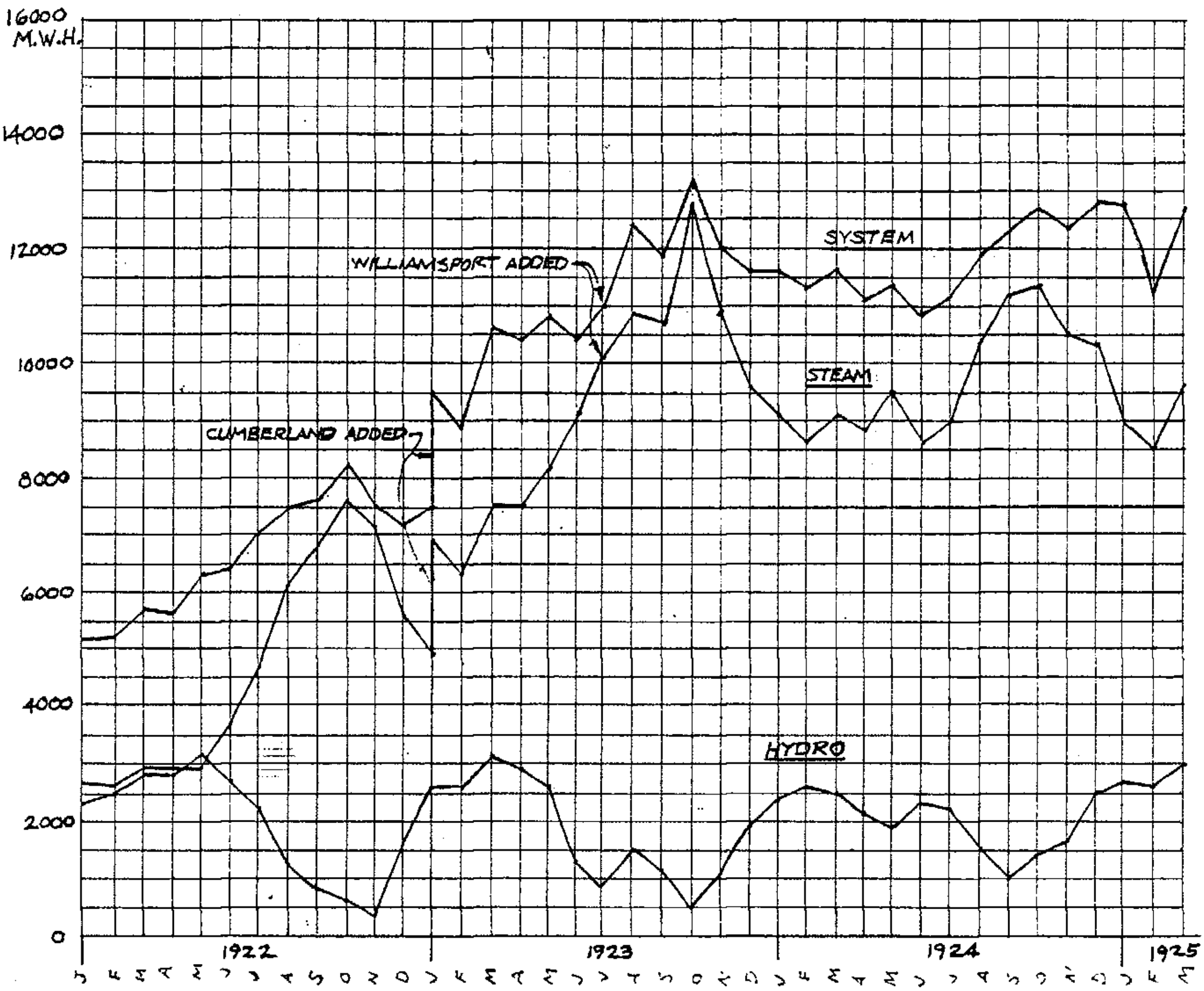
TABLE 12

1923	Total System Output (kWh)	Total Steam Output (kWh)	Percent of System Output	Total Hydro Output (kWh)	Percent of System Output	Combined Dam 4 and Dam 5 Output (kWh)	Percent of Total Hydro Output	Percent of System Output
January	9,522,800	6,949,620	72.97	2,573,180	27.03	1,410,530	54.82	14.81
February	8,856,950	6,279,365	70.90	2,577,585	29.10	1,062,035	41.20	11.99
March	10,578,422	7,506,202	70.96	3,072,220	29.04	1,365,170	44.44	12.90
April	10,419,165	7,514,990	72.13	2,904,175	27.87	1,324,625	45.61	12.71
May	10,828,842	8,208,072	75.80	2,620,770	24.20	1,501,720	57.30	13.86
June	10,399,585	9,058,163	87.10	1,341,420	12.90	835,870	62.31	8.03
July	11,017,425	10,125,875	91.91	891,550	8.09	546,940	61.35	4.96
August	12,387,478	10,907,598	88.05	1,479,880	11.95	882,439	59.63	7.12
September	11,899,886	10,670,021	89.67	1,229,865	10.33	708,665	57.62	5.95
October	13,244,769	12,810,669	96.72	434,100	3.28	163,850	37.74	1.23
November	11,979,934	10,875,684	90.78	1,104,250	9.22	737,950	66.83	6.15
December	11,617,485	9,581,375	82.47	2,036,110	17.53	1,141,960	56.09	9.82
Total 1923	132,752.739	110,487,634	83.23	22,265,105	16.77	11,681,754	52.47	8.80
1924								
January	11,602,980	9,208,935	79.37	2,394,045	20.63	1,064,395	44.46	9.17
February	11,320,550	8,716,180	76.99	2,604,370	23.01	1,309,470	50.78	11.56
March	11,670,538	9,161,958	78.51	2,508,580	21.49	982,130	39.15	8.41
April	11,048,448	8,821,288	79.84	2,227,160	20.16	862,170	38.71	7.80
May	11,401,093	9,484,693	83.19	1.916,400	16.81	1,003,000	52.34	8.79
June	10,889,667	8,605,922	79.03	2,283,745	20.97	1,245,170	54.52	11.43
July	11.237.813	9,039,238	80.44	2,198,575	19.56	1,293,600	58.84	11.51
August	11,850,083	10,321,133	87.10	1,528,950	12.90	860,500	56.28	7.26
September	12,255,885	11,294,290	92.15	961,595	7.85	668,470	69.52	5.45
October	12,755,356	11,365,221	89.10	1,390,135	10.90	1,016,110	73.09	7.96
November	12,284,395	10,552,435	85.90	1,731,960	14.10	772,410	44.60	6.28
December	12,872,143	10,357,643	80.47	2,514,500	19.53	1,346,680	53.56	10.46
Total 1924	141,188,951	116,928,936	82.82	24,260,015	17.18	12,424,105	51.21	8.80

(compiled from various Potomac Edison Company files)

FIGURE 12

POTOMAC EDISON SYSTEM OUTPUT (1922-1925)



THE POTOMAC EDISON COMPANY -

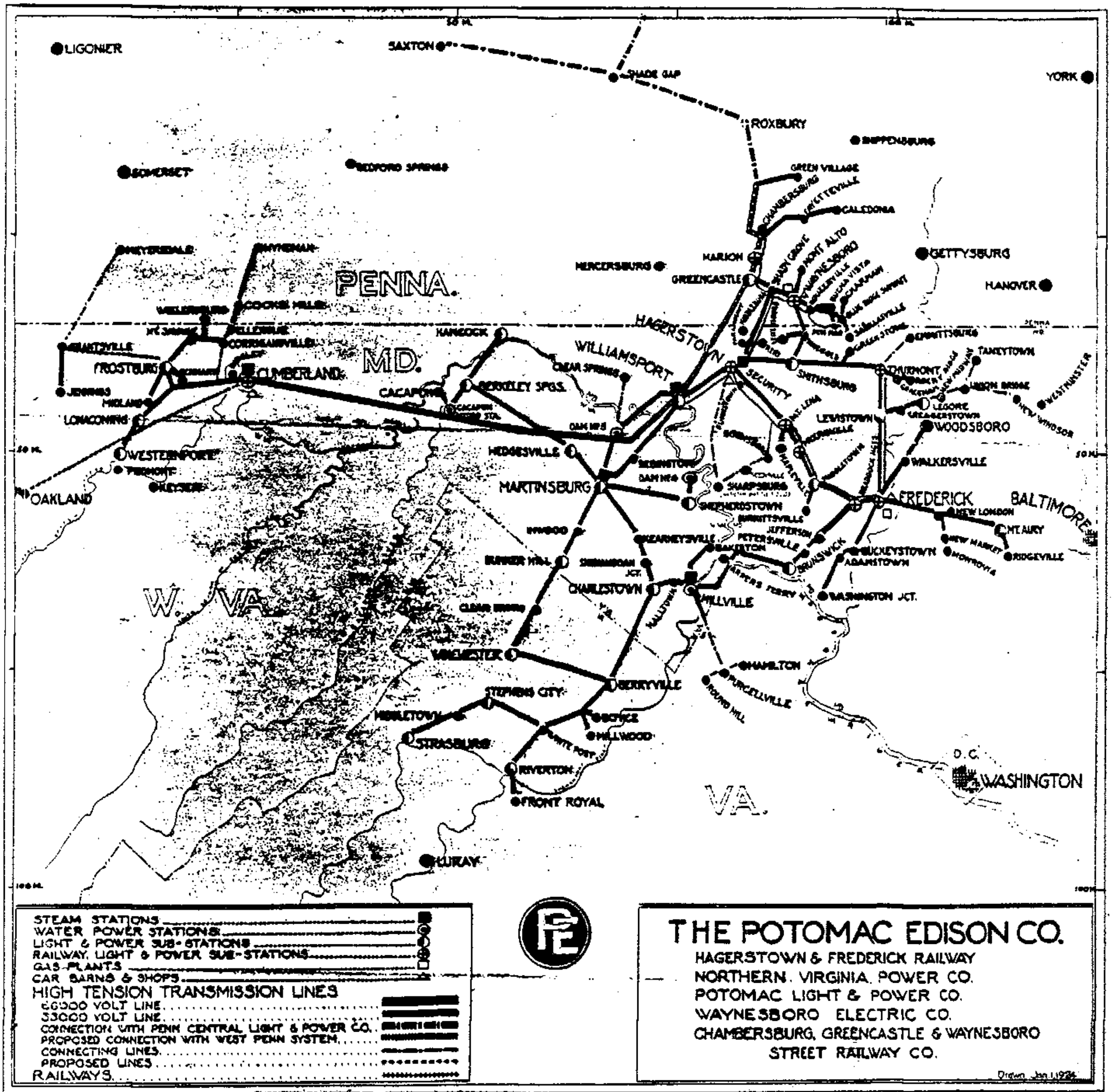
SYSTEM, STEAM AND HYDRO MONTHLY MEGAWATT - HOUR OUTPUT

JAN. 1922 TO MAR. 1924

(BASED ON MATERIALS FROM POTOMAC EDISON COMPANY MISCELLANEOUS HISTORICAL FILES)

FIGURE 13

MAP OF POTOMAC EDISON COMPANY (1924)



Source: Potomac Edison Company miscellaneous historical files volt outdoor substation tower fell into the live wiring, and this accident produced an electrical short circuit which activated the governor controlling the number one turbine, completely shutting down the unit. The abrupt shock sustained by the turbine in the process of being brought to a halt apparently loosened or broke off parts of the wheel casing, guide vanes, and wicket gates, which had, apparently, been loose for some time. After the turbine was restarted the damage to the wicket gates became apparent and, as water continued to flow through the turbine, the unit began rotating at an uncontrollably high speed. An attempt was made to stop the water from reaching the turbine by closing the headgates, but because the velocity of the water increased as the headgate opening decreased, the gates only partially closed. The hand brake, a large wooden block pushed against the flywheel by a manually operated lever, also failed to stop or even slow down the runaway water wheel. Finally, as a last resort, someone at the plant allegedly brought the turbine to a halt by dropping at least one heavy steel angle iron into the scroll case. [41] An inspection of the turbine revealed that all the wicket gates, gate pivot bolts, and guide vane bolts were sheared off, the top of the gate pivot was bent, the inlet edges of the runners were either bent or broken off, and all the guide vanes and the links connecting the gate to the gate ring were damaged. Since the damage was, in the words of the Leffel engineer sent to inspect the turbine, "so complete," the turbine was removed from the plant and returned to the Leffel factory for repair and the installation of a new set of runners. [42]

PLANS FOR MORE POWER FROM DAM 4

After assessing the damage at the Dam 5 plant, the Leffel engineer visited the Dam 4 plant and examined the condition of the horizontal turbines installed at the plant. He found no problems with these units and, while at the plant, suggested that the unused third penstock would be an "ideal setting" for a vertical shaft, direct connected turbine-generator unit and voiced the opinion that reconstruction of the plant to accomodate the new equipment would involve only a "small expense." He also discussed the feasibility of installing the new vertical unit and removing one of the horizontal units; replacing both horizontal units with vertical units; and installing three vertical units. [43]

Potomac Edison's enthusiasm for installing a third unit at the Dam 4 plant was tempered by the recognition that at the Dam 4 plant the operating head dropped by one foot when both turbines were running. The Leffel engineer cautioned that if the tail race were to rise under this condition that the operating head on all three units might be significantly reduced with a consequent reduction in the horsepower produced. He suggested that either cleaning out the tailrace or, if possible, deepening it might minimize the loss of head should a third unit be installed. [44] This serious concern with the head available with the installation of a third turbine most likely dissuaded Potomac Edison from accepting any of the Leffel Company proposals.

One reason for the lack of sufficient water for a third unit, despite the 1924 termination of operations on the C&O Canal, was the severe leakage of water through the dam. In 1925 low water conditions permitted Potomac Edison engineers to locate the source and cause of the leaks which had "baffled" both the engineering and operating departments for years. By dumping a coloring agent, potassium permanganate, into the Potomac just above Dam 4, Potomac Edison's engineers "conclusively" determined the source and size of the leaks and concluded that, given the small amount of equipment at the plant, the annual flow duration curve, and the additional kilowatts to be obtained from the saved water, Potomac Edison "could not justify the expenditure of very much money to stop the leakage." [45]

The reluctance to spend large sums to plug the leaks in Dam 4 was one measure of the declining importance of the Dam 4 and Dam 5 plants. The 1926 installation of a 30,000 kW steam turbine generator pushed the Williamsport plant's installed capacity to 45,000 kW, giving it 56 percent of Potomac Edison's 80,750 kW capacity and allowing the plant to carry Potomac Edison's base load without assistance. The expansion of the Williamsport plant pushed the percent of system generating capacity installed at the Dam 4 and 5 plants down to three percent. Despite the two plant's declining importance, their relatively low maintenance costs assured their continued operation. At Dam 4, for example, the rope drive sheave wheels were regrooved for the first time in 1926 after 20 years of continuous operation. [46]

In 1929, with the Martinsburg plant scrapped and the Chesapeake and Ohio Canal closed, leaving all the Potomac River water available for power generating purposes, conditions seemed more advantageous to the installation of a third unit at the Dam 4 plant. The Leffel Company submitted seven different proposals for the installation of a vertical shaft turbine in the still unused third penstock. One of the proposals even suggested installing two small vertical shaft turbines in the single penstock. In all but the dual turbine proposal, the center line of the turbine shaft was to be located 21 feet from the existing bulkhead wall. An extension of the building was to rise up from and above the existing open penstock to house the new unit at the same height as the two existing generators. A new penstock floor was to be constructed to house the circular steel draft tube required by the vertical shaft turbine. [47] With the onset of the depression in 1929, however, Potomac Edison once again chose to leave the third penstock unused.

Concern with increasing leakage at the dam, the loss of effective head, crumbling and sinking masonry, and the total collapse of Dam 4's north abutment prompted Superintendent of Power A. D. Lewis to investigate the feasibility of using asphalt grouting to seal the dam's cracks and fissures and reduce the estimated 250 to 300 cubic feet per second of water leaking through them. [48] Except for dumping a large amount of cinders behind the dam, however, no effort was made during 1930 to plug leaks and in April 1931 Superintendent Lewis, still concerned about the settling of the masonry in the dam wall on the Maryland side, wrote Chesapeake and Ohio Canal Company General Manager Nicolson and suggested they meet to discuss this problem. [49] Once again, however, no action was taken.

THE 1936 FLOOD

The winter of 1935 - 1936 was "exceptionally severe." [50] The three foot thick ice which had formed on the Potomac clogged the river during a late winter thaw, and on February 27, 1936 ice punctured the northern end of Dam 4. The swirling, ice-laden water swept away a 40 foot long section of the dam, [51] however, even more serious damage was forthcoming.

On March 17, 1936, swollen by seven inches of rain, the Potomac began rising to record levels. At 7:57 PM, with water approximately ten feet above the top of the dam, operators at the Dam 5 plant shut down both of the plant's generating units. Within two hours, both of Dam 4 plant's two sets of water wheels were shut down as water flowed as much as six feet above the crest of Dam 4. The Potomac, continuing to rise, did not reach maximum flood crest until 10 PM on March 18 at Dam 5 and 2 AM on March 19 at Dam 4. At Dam 5 the raging, mud and debris laden water reached a maximum of thirteen feet and three inches above the generating room floor (see HAER photo WV-28-50 and 51). This level was twenty feet higher than the record 1924 flood. At the height of the flood the generator floor of the Dam 4 plant was beneath six feet three inches of muddy, debris-filled water. [52] The United States Geological Survey gauges at Shepherdstown, West Virginia, five miles downstream from Dam 4, recorded the flood crest at 6 AM March 19, when the Potomac's flood flow reached an estimated 335,000 cubic feet per second, 60 times the average flow. [53] Figures 14 and 15 graph the flood flow at Dams 4 and 5.

As the flood waters gradually receded, the magnitude of the destruction slowly became visible. At the Dam 5 plant, debris laden water had battered and broken windows, swept away the plant's interior office and all the office equipment, and caked the walls, floor, and both the inside and outside of all the

FIGURE 14

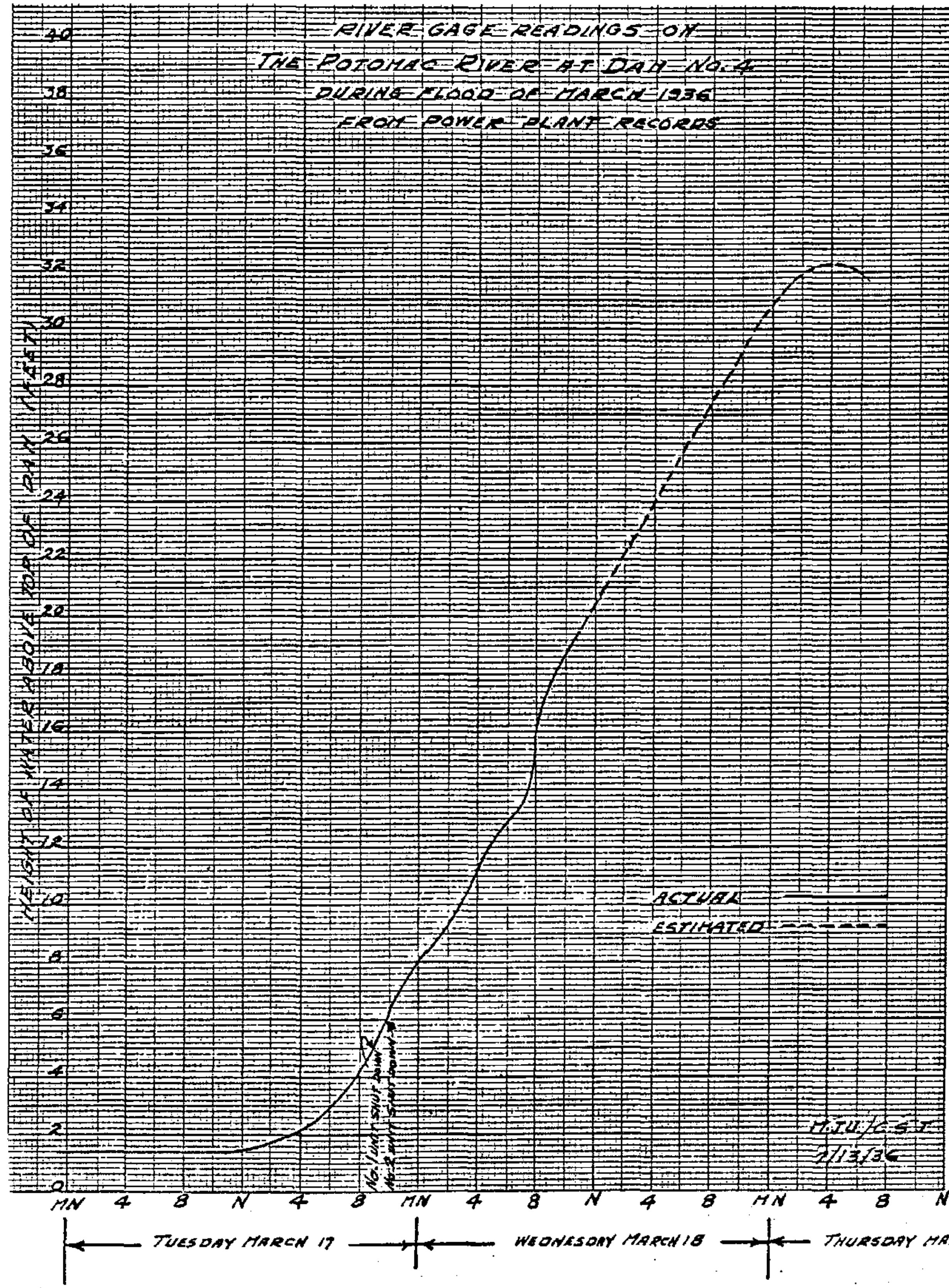
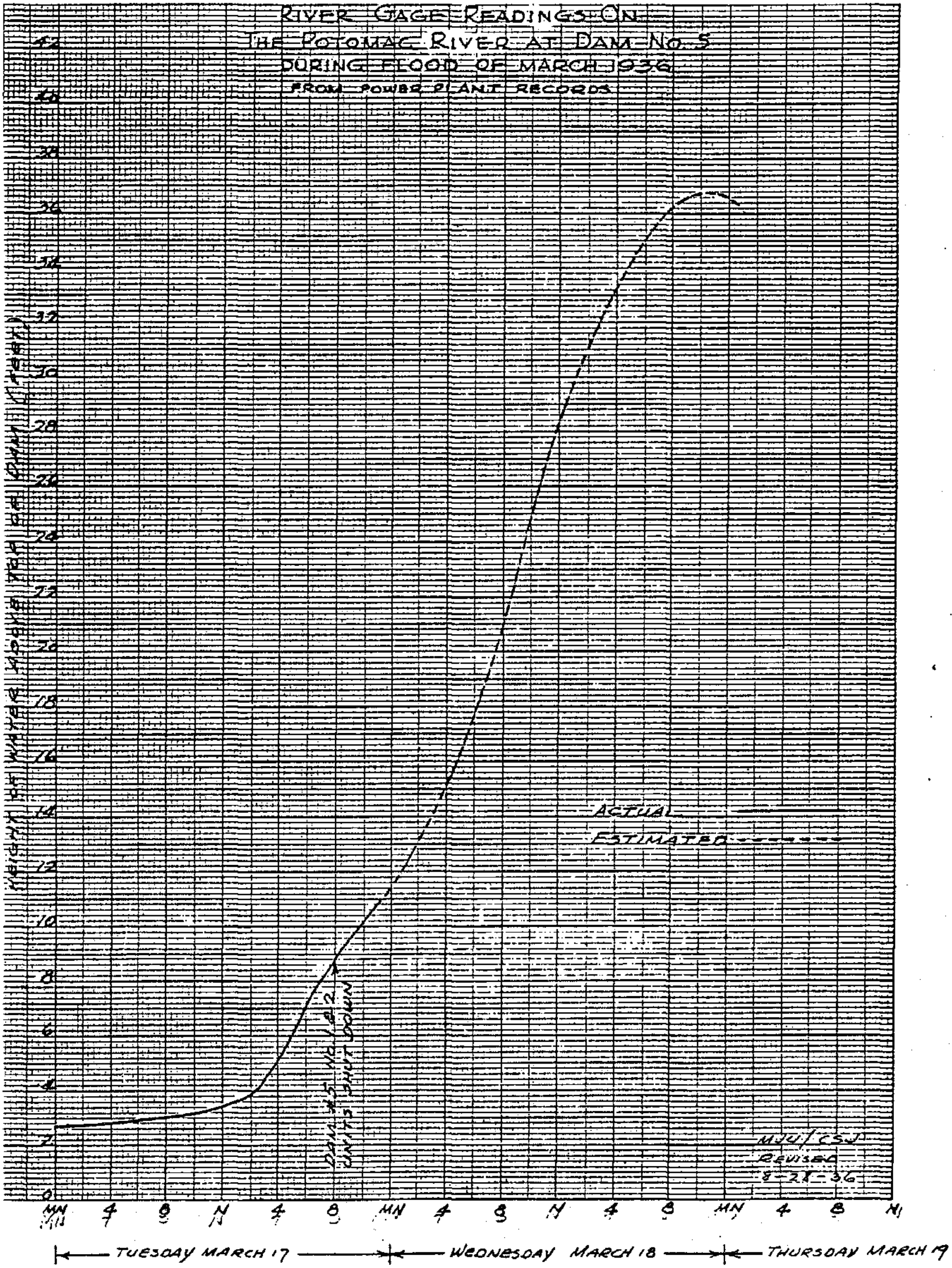

RIVER GAGE READINGS ON
THE POTOMAC RIVER AT DAM NO. 4
DURING FLOOD OF MARCH 1936
FROM POWER PLANT RECORDS
HEIGHT OF WATER ABOVE TOP OF DAM (FEET)
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
ACTUAL
ESTIMATED
MN 4 8 N 4 8 MN 4 8 N 4 8 MN 4 8 N
TUESDAY MARCH 17
WEDNESDAY MARCH 18
THURSDAY MARCH 19
M.J.U./C.S.T.
7/13/36

FIGURE 15


RIVER GAGE READINGS ON
THE POTOMAC RIVER AT DAM No. 5
DURING FLOOD OF MARCH 1936
FROM POWER PLANT RECORDS
HEIGHT OF WATER ABOVE TOP OF DAM (FEET)
ACTUAL
ESTIMATED
DAM #5 NO. 1 & 2 UNITS SHUT DOWN
MJU/CSJ
REVISED
8-28-36
MN
4
8
N
TUESDAY MARCH 17
WEDNESDAY MARCH 18
THURSDAY MARCH 19

electrical equipment with mud. The flood waters had also submerged the lower half of the plant's substation (see HAER photo WV-28-50), destroying all three transformers. The Dam 4 plant sustained somewhat more damage. Here, the flood had filled the forebay with debris; broken headgate gear hoist mechanisms and plant windows; swept away the wooden walkways above the open penstocks; warped the wooden generator floor; filled the sheave wheel pits with muddy water; and deposited mud and debris on the generator floor and inside the generating equipment and switchboard. Dam 4 itself sustained the most extensive damage: a gaping 55 foot wide break 45 feet south of the Maryland abutment. [54]

The severe damage sustained by Dam 4 prompted Potomac Edison to defer an immediate effort to restart this plant and instead concentrate on a rapid restart of the Dam 5 plant. Restoring the Dam 5 plant required cleaning the interior of the plant, and cleaning, drying, and, where necessary, repairing all the electrical equipment. All the electrical equipment except the generators and governors was removed and transported to Williamsport and Hagerstown for cleaning, drying, and repairing. After washing down and cleaning the generator and governors, an exciter was imported from Potomac Edison's Millville, Virginia plant and the drying of the generator by "short circuit" was begun. Generator number two was placed in service on April 4 and, after repairing a faulty coil in generator number one, this unit was dried and placed in operation on April 10. [55]

Repeating the procedure at the Dam 4 plant, workmen removed all the electrical equipment except the generators and governors and transported it to Hagerstown and Williampsort for cleaning, drying, and repairing. After cleaning and repairing both exciters, generator number two was restarted and dried. Because the field coils of generator number one had been "giving trouble" before the flood, they were repaired at Hagerstown before the unit was restarted. [56] On April 14, unit two was placed in operation, however, unit one was not started until May 2. Because of a lack of sufficient water to operate both units simultaneosuly, unit one had to be removed from service to allow unit two to resume operating. [57]

The most serious impediment to restoring the Dam 4 plant was the repair of the gaping hole in the northern half of the dam (see HAER photos WV-27-41 through 46). During May and June the dam impounded barely enough water to operate one turbine-generator unit and as the summer low flow season approached, pressure to repair the dam grew. [58] Negotiations with the Chesapeake and Ohio Canal Company produced a contract stipulating that Potomac Edison would assume the full cost of repairs and that the Canal Company would contribute the equivalent of $15,000 by suspending the $1,500 annual water rent on Dams 4 and 5 for ten years. [59]

Potomac Edison's engineers concluded that a curved, reinforced concrete cap would "discharge flood waters faster and back up flood waters less" than the old angular wooden ice guards. [60] Figure 16 illustrates the curved concrete cap added to the dam after the 1936 flood. The concrete cap also raised the height of the dam by one foot and the increase in the normal head, from 17 feet 4 inches to 18 feet 4 inches, promised to increase the Dam 4 plant's average annual output by as much as 400,000 kilowatt hours per year. [61]

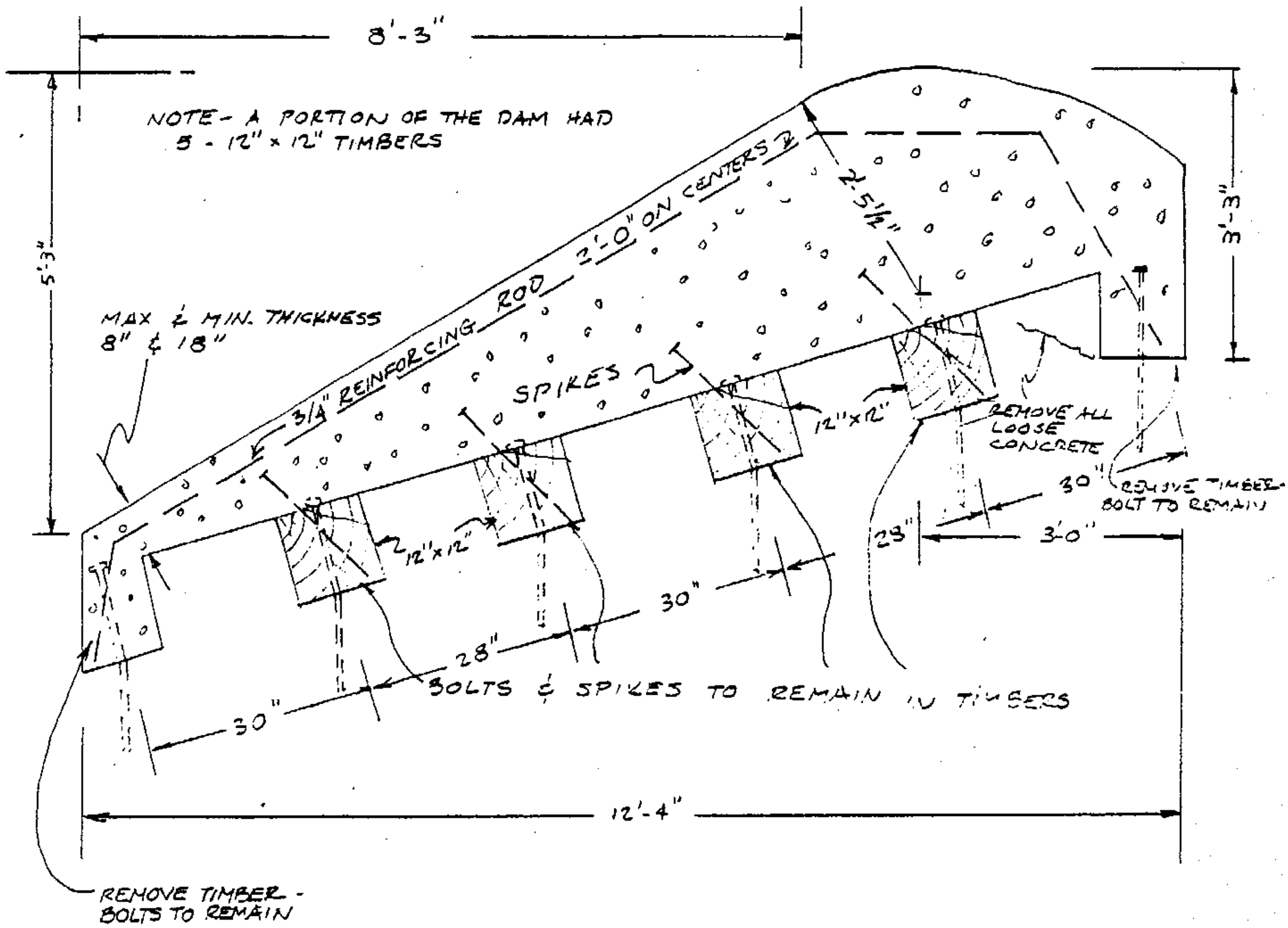
Potomac Edison solicited estimates for repairs and, after evaluating four proposals, selected Sanderson and Porter to supervise the Dam 4 reconstruction project. Before reconstruction of the dam could begin, Sanderson and Porter had to procure a convenient supply of clay, import a one cubic yard Erie steam shovel and a number of dump trucks, construct eighty feet of new roadway, reinforce a wooden bridge across the C&O Canal, and string a three-phase line across the Potomac to the Maryland abutment to illuminate lights and run pumps at the construction site. To channel as much of the stream flow as possible through the plant instead of over the dam, parts of the water wheel pit floors were removed. [62]

The first step in actually repairing the dam was building an eight foot wide, 350 foot long primary upstream cofferdam and a system of flumes to carry water leaking through the cofferdam through the break in the dam. An eight foot wide, 210 foot long downstream cofferdam and four foot wide secondary cofferdams, both above and below the opening, were also erected and three centrifugal pumps installed to remove water from the construction space between these secondary cofferdams. Workmen cleared the riverbed until reaching bedrock, drove reinforcing rods vertically into the streambed to anchor the concrete patch, erected wooden forms on both sides of the dam, and poured 595 cubic yards of concrete into the forms to close the break. With the break in the dam closed, workmen proceeded to pour an additional 730 cubic yards of concrete to cap the dam. The original wooden gate at the head of the unused third wheel pit was also replaced with a stationary steel bulkhead before the plant resumed operation. [63]

The increased head and reduced leakage at Dam 4 resulted in a "substantial increase" in electrical output at the Dam 4 plant. [64] The operating and engineering department reported that while the volume of flow at Dam 4 was greater than at Dam 5, because of the "large amount of leakage at Dam 4" the Dam 5 plant had "always generated more power." For example, during the 1930 drought, the Dam 5 plant produced "some power" while at Dam 4 "practically all" the water leaked through the dam. [65] On December 10, 1936, the operating and engineering department reported that since the reconstruction of Dam 4, the output of the

FIGURE 16

SECTION, DAM 4 CONCRETE CAP (1936)



BASED ON
POTOMAC EDISON COMPANY DRAWING 2492-510-A1 (F1)
DAM #4 - CONCRETE CAP PIECE AS BUILT
DATE: 11/24/36

plant's "much older and less efficient" equipment had exceeded the output of the Dam 5 plant under both high and low flow conditions. [66]

The repair and reconstruction of Dam 4 was the last major capital construction project at either Dam 4 or 5, but not the last alteration of the two Potomac River hydroelectric plants. At the Dam 5 plant, Potomac Edison investigated but did not replace the roller type generator thrust bearings with "Kingsbury" type thrust bearings. Operators at the plant had experienced difficulties with the roller bearings since the opening of the plant. In 1923, Potomac Edison had installed larger rollers and plates and reduced the thickness of the leveling plates to accommodate this change. Despite this alteration, problems continued; the bearings ran hot, rollers splintered and cracked, and the roller plates required constant renewal and refacing. These roller bearing problems resulted in periodic shut downs of the generators, however, despite these problems Kingsbury thrust bearings were not installed. [67]

In 1959, at the request of Potomac Edison, a Leffel Company engineer inspected the hydraulic equipment at both the Dam 4 and 5 plants. Because Potomac Edison felt that the Dam 5 plant's number one turbine, rebuilt in 1925, was in "good condition," and did not want to shut this unit down, the Leffel engineer inspected only the number two water wheel. [68] He found the turbine shaft running "very true" and displaying very little wear after so many years of continuous service. [69] He did discover the "lignum vitae" bearing blocks to be very badly worn and in need of immediate replacement. He also recommended replacing the 40 gate washers and 20 gate bolts and, reminding the company of the 1925 accident with turbine number one, warned: "if one of these bolts breaks off and allows the gate to get into the runner, then considerable damage will result." [70] Potomac Edison was advised that while the turbine runners were in good condition, they did need to be scraped free of barnacles, sandblasted, and repainted. [71]

Reviewing the inability of the utility to operate both turbines at full load during low flow periods, the Leffel engineer suggested replacing the turbines' type "Z" runners with type "S" runners. Despite the ability of the type S runners to produce ten percent more power using the same volume of water, [72] Potomac Edison chose not to replace the turbine runners at the Dam 5 plant.

At the Dam 4 plant, the inspection revealed that in both sets of turbines, all the "lignum vitae" thrust blocks, responsible for aligning the runners in the gate casing, were badly worn and in need of immediate replacement. The number one turbine, on the side closest to the river, required new gate casings to reduce the amount of excess, wasted water flowing around two of the four runners. Replacing two of the four runners was also recommended. The Leffel Company quoted Potomac Edison a price of $1,120 for eight lignum vitae thrust blocks and $11,815 for the two gate casings and two runners welded to a new shaft. [73]

The inspection of the Dam 4 plant took place while the plant was out of operation to allow a Potomac Edison construction crew to install new pit gates and trash racks and pour a three inch thick concrete floor atop the wooden planks in both of the two open penstocks equipped with turbines, and replace switch gear and switchboard instruments. [74] The Dam 4 plant underwent no other significant alterations until 1961 when the original slate roof was removed and replaced by asphalt shingles. [75]

CURRENT OPERATIONS

Today the Dam 4 and 5 plants are part of the Potomac Edison-Allegheny Power System. In 1971, the combined output of the Dam 4 and 5 plants was two hundredths of one percent of the Allegheny Power System's 4,512.3 megawatt total system output.

Since the installation of semi-automatic controls in 1952, the plants are staffed part-time by operators who perform routine maintenance on a regular daily schedule. A roving Potomac Edison field crew performs major and emergency repairs. At both plants the turbines are inspected once a year. The plants can operate when the flow is as low as 190 cfs and are turned off when the flow is greater than 44,000 cfs. In between these two extremes, the plants operate continuously with full gate openings. With both of the broken turbine shafts at the Dam 4 plant having been replaced during 1980, both the Dam 4 and Dam 5 plants are operating at maximum output. The only threat to the continued operation of the plants is the future availability of "lignum vitae" bearing blocks and sisal rope.

A POSTSCRIPT

The durability, reliability, and economy of the hydraulic and electrical equipment at the Dam 4 and 5 plants contributed much to the continued operation of the two hydro plants. While other small hydro plants became uneconomical and ceased to operate during the 1950s and 1960s, Potomac Edison's two Potomac River hydro plants produced a small but relatively constant part of the utility's system output. After 1973, as both fossil fuel prices and electric rates rose to previously unanticipated heights, small hydroelectric plants once again became economically viable, often potentially lucrative, means of meeting increased electric demand or reducing dependence on petroleum as a fuel for generating electricity. Responding to the new economics, Potomac Edison, in 1979, commissioned the New York City based consulting engineering firm of Abbots, Tibets, McCarthy, Stratton, to investigate the technical and economic feasibility of increasing the output of the Dam 4 plant by installing a third turbine-generator unit.

An analysis of the 50 year flow duration curve indicated that, with the Potomac's 5,900 cfs average and 3,000 cfs median flow, the generating capacity of the Dam 4 plant could be doubled by installing a third turbine and generator and by upgrading the turbines and generators already in operation. [76] Expanding the generating capacity of the plant without altering either the internal structure or the external appearance of the building (the primary constraint imposed upon the consulting engineers by Potomac Edison) limited both the types and sizes of hydraulic equipment that could be installed.

A vertical shaft turbine was rejected because too much modification of the plant was required. As a result, the engineers examined the technical and economic feasibility of four alternative horizontal shaft turbines: a "bulb" turbine connected to a submerged high speed generator; two sizes of standardized "tube" type turbines; and a pair of horizontal Francis turbines connected to a horizontal shaft generator by the use of a rope drive system. The first two alternatives, the bulb and the three meter diameter tube turbine, would have required significant alterations to the building, penstock, and tailrace. Alternative three, the two meter diameter tube turbine could have been installed with only slightly less alteration. The fourth alternative, tandem Francis turbines, required no external, visible modification of the building and only minor alterations to the sheave wheel pit and generator room floor. Coupled to the Francis turbines by a rope drive system similar to that used by generators 1 and 2 would be a high speed, synchronous type horizontal shaft generator rotating at 360 revolutions per minute and capable of generating 900 kW of 4,160 volt alternating current. [77]

After carefully evaluating all the technical and financial aspects of eight variations of the four basic alternatives, the consulting engineers concluded that the tandem Francis horizontal turbines and rope-driven horizontal shaft generator would best satisfy the objectives of leaving unaltered both the structure and facade of the building and minimizing costs relative to the increased output obtainable from the new equipment. [78] Table 13 succinctly illustrates the estimated costs, in 1980 dollars, and electric output of the various alternatives. The two critical variables, the degree of alteration to the power house (line 8) and the costs per unit of output (lines 6 and 7) clearly recommend the installation of the Francis turbines. The reduction of future maintenance expenses on the original equipment made the alternative of installing new equipment and upgrading the old equipment the most desirable proposal despite a minor cost disadvantage when compared to installing only new equipment and leaving the original equipment unaltered.

TABLE 13

COMPARISON OF DAM 4 PLANT EXPANSION PROPOSALS

Alternative	Existing Equipment	Upgraded Equipment	Upgraded Equipment with High Speed Generator	Francis Turbine & Upgraded Equipment	Francis Turbine & Existing Equipment	Francis Turbine, High Speed Generator, Existing Equipment	2.5 Meter Bulb Turbine & Existing Equipment	3 Meter Tube Turbine & Existing Equipment	2 Meter Tube Turbine & Existing Equipment
Discharge (cfs)	940	1,100	1,100	1,800	1,640	1,640	2,230	2,500	1,530
Power (kilowatts)									
Units 1 & 2	1,140	1,400	1,400	1,400	1,140	1,140	1,140	1,140	1,140
Unit 3	-----	-----	-----	900	900	900	1,750	2,000	750
Average Annual kWh	8,900,000	10,800,000	10,800,000	16,100,000	14,700,000	14,700,000	19,700,000	21,000,000	13,700,000
Incremental Average Annual kWh	---------	1,900,000	1,900,000	7,200,000	5,800,000	5,800,000	10,800,000	12,100,000	4,800,000
Cost (1979 $)	---------	$330,000	$543,000	$1,414,000	$1,084,000	$1,205,000	$2,995,000	$3,214,000	$1,600,000
Cost Per kWh ($)	---------	$1,270	$2,090	$1,220	$1,205	$1,340	$1,710	$1,610	$2,133
Cost Per kWh (Mills)	---------	33	54	37	35	39	52	50	63
Modification to Power House	None	None	Minor	Minor	Minor	Minor	Major	Major	Moderate

Source: Tippetts, Abbett, McCarthy, Stratton, Engineers and Architects, "Potomac River Dam No. 4 Hydroelectric Development Expansion Study," January 1980.

FOOTNOTES: CHAPTER VI

[1] PL&PC Annual Meeting, WV Stockholders Records, January 28, 1919.

[2] Ibid.; WVPSC, Annual Report 1917, pp. 38-39.

[3] H&F Minutes, January 16, March 10, 1919; PL&PC Minutes, April 7, 1919; PL&PC Annual Meeting, WV Stockholders Records, January 28, 1919.

[4] Moody's Analysis of Investments 1920, p. 1438; H&F Minutes, April 7, 1919; WVPSC, Sixth Annual Report 1918-1919, p. 687.

[5] Moody's 1920, p. 1434.

[6] H&F Minutes, April 9, 1919; H&F Minutes, January 16, 1919.

[7] D.M. Swink to Lewis F. Cooper, NVPC Minutes, January 21, 1919.

[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] NVPC Minutes, March 24, 1919.

[12] Ibid.; NVPC Minutes, May 21, June 18, July 16, 1918, February 18, 1919.

[13] NVPC Minutes, April 19, April 26, May 13, 1919; WVPSC, Sixth Annual Report; H&F Minutes, April 10, May 15, 1919.

[14] Shepherdstown Register, May 15, May 29, 1919; NVPC Minutes, May 23, 1919; PEC Historical File: H&F; Moody's Analysis of Investments 1920, p. 1434; Poors, p. 2028.

[15] NVPC Minutes, May 23, June 1, June 16, June 17, June 30, September 22, 1919; WVPSC, Annual Report 1921, pp. 186-188, 235.

[16] H&F Annual Report December 31, 1920.

[17] Shepherdstown Register, June 15, 1919; NVPC Minutes, June 16, 1919; H&F Minutes, March 10, 1919, February 23, September 25, October 25, 1920.

[18] H&F Minutes, January 5, February 23, 1920; NVPC Minutes,

November 21, 1919; "Structures and Generating Station Equipment," p. 153, PEC.

[19] H&F Annual Report, Year ending December 31, 1920.

[20] Ibid.

[21] H&F Minutes, May 31, 1920.

[22] H&F Annual Report, Year ending December 31, 1920.

[23] Ibid.; H&F Minutes, February 23, 1920.

[24] H&F Annual Report, December 31, 1920.

[25] Ibid.

[26] H&F Annual Report, Year ending December 31, 1921; C.M. Harris to E.M. Coblentz, NVPC Minutes, December 18, 1920.

[27] H&F Annual Report, Year ending Deceber 31, 1921.

[28] Ibid.; NVPC Minutes, April 11, April 14, 1921; H&F Annual Report, Year ending December 31, 1920.

[29] H&F Annual Report, Year ending December 21, 1921.

[30] PL&PC Minutes, April 21, 1922; WVPSC, Annual Report 1922, p. 279; NVPC Minutes, April 7, April 10, 1922; PEC Historical File: NVPC, April 19, 1922; H&F Annual Report, December 31, 1921.

[31] Ibid.; PL&PC Minutes, September 7, 1922; PPSC Annual Report, Year ending December 31, 1922; PEC Historical File: H&F.

[32] "Account of the Development of the Potomac Edison Company and Subsidiary Companies," testimony of R. Paul Smith before the Maryland Public Service Commission, June 30, 1939, pp. 17, 25-26, PEC; PL&PC Minutes, September 7, 1922; H&F Minutes, March 28, 1922; PPSC Annual Report, Year ending December 31, 1922.

[33] PL&PC Minutes, May 23, 1922.

[34] PL&PC Minutes, May 23, June 27, July 25, 1922, March 27, 1923.

[35] PL&PC Minutes, March 28, October 31, December 4, 1922.

[36] G.L. Nicolson to PPSC, October 10, 1922, Dam 5 File, PEC Minor Stations; PL&PC Minutes, June 27, October 31, December 4, December 19, 1922, January 30, February 27, March 27, June 26, August 29, November 27, December 19, 1923.

[37] PL&PC Minutes, September 25, 1923; PEC First Annual Report.

[38] PL&PC Minutes, February 25, May 26, 1925, June 29, 1926, March 29, September 27, 1927; PEC First Annual Report, PEC Second Annual Report, PEC Third Annual Report, PEC Fourth Annual Report, PEC Fifth Annual Report; Dam 5 File, PEC Minor Stations.

[39] Sanderlin, Great National Project, pp. 276-277, 289; PL&PC Minutes, April 29, May 27, June 24, July 29, August 26, September 30, 1924, July 27, 1926; PPSC Annual Report, December 31, 1922.

[40] H&F Minutes, December 18, 1923; PL&PC Minutes, August 26, September 30, 1924, April 25, November 24, 1925, July 27, 1926; Leffel to PEC, December 1, 1925, PEC Minor Stations; Interview with Robert L. Saunders, Pikeside, W.V., August 5, 1980.

[41] Leffel to PEC, December 1, 1925, PEC Minor Stations.

[42] Ibid.

[43] Leffel to PEC, December 1, 1925, PEC Minor Stations; Drawing 34736, PEC Minor Stations.

[44] Leffel to PEC, December 1, 1925, Dam 5File, PEC Minor Stations.

[45] PL&PC Minutes, September 29, 1925; C.M. Harris to G.L. Nicolson, July 8, September 5, September 21, 1925, C&O Papers, NA.

[46] A.D. Lewis to American Asphalt Grouting Company, August 29, 1930, Dam 4 File, PEC Minor Stations.

[47] Drawings 38366-38370, December 1929, PEC Minor Stations.

[48] A.D. Lewis to G.L. Nicolson, September 10, September 22, 1930, C&O Papers, NA; A.D. Lewis to American Asphalt Grouting Company, August 29, 1930, S&P to G.S. Humphrey, August 20, 1930, Dam 4 File, PEC Minor Stations.

[49] A.D. Lewis to G.L. Nicolson, April 22, 1931, A.D. Lewis to G.S. Humphrey, September 13, 1930, Dam 4 File, PEC Minor Stations; Martin J. Urner, "Report on the 1936 Repairs and Improvements at Dam Number 4," December 10, 1936, p. 1.

[50] Ibid., p. 2.

[51] Ibid.; G.W. Burgen to G.L. Nicolson, with newspaper article attached, February 29, 1936, C&O Papers, NA.

[52] "Report of 1936 Flood Damage to Potomac Edison Company," PEC, pp. 35-36.

[53] United States Geological Survey, *Water Supply Paper 801* (Washington, D.C.: Government Printing Office, 1937), p. 99.

[54] Urner, "Report on 1936 Repairs," pp. 2; "Report of 1936 Flood Damage," pp. 35-36, 42-43; PEC Annual Report, Year ending December 31, 1936.

[55] "Report of 1936 Flood Damage," pp. 35-36, 42-43.

[56] Ibid.

[57] Ibid.; Urner, "Report on 1936 Repairs," p. 2.

[58] Ibid.

[59] Ibid., pp. 2-3; "Contract with the Chesapeake and Ohio Canal Company Covering the 1936 Repairs to Dam Number 4," July 28, 1936, Appendix to Urner, "Report on 1936 Repairs," pp. 8-11.

[60] Ibid., p. 2.

[61] Ibid., p. 3.

[62] Ibid., pp. 2-4.

[63] Ibid., pp. 3-5; Drawing 2469-510, PEC Minor Stations.

[64] Urner, "Report of 1936 Repairs," p. 7.

[65] Ibid.

[66] Ibid.

[67] PEC to Leffel, July 3, 1936, Leffel to PEC, July 7, 1936, EM to Leffel July 22, 1936, James Leffel and Company, File AB-9592.

[68] Leffel to PEC, August 26, 1959, PEC Minor Stations Files.

[69] Ibid.

[70] Ibid.

[71] Ibid.

[72] Ibid.

[73] Ibid.

[74] Tippetts-Abbett-McCarthy-Stratton, Engineers and Architects, "Potomac River Dam No. 4 Hydroelectric Development Expansion Study," New York, January 1980, Office of Generation Planning, Allegheny Power System, Greensburg, Pennsylvania.

[75] Ibid.

[76] Ibid.

[77] Ibid.

[78] Ibid.

CONCLUSION

The differences in the design of the three hydroelectric plants built on the Potomac River between 1903 and 1918 very clearly reveal the advances in mechanical and electrical engineering during two decades of rapid growth and expansion of the electric utility industry. A comparison of the equipment found in the two operating Potomac River plants and the original Dam 5 plant vividly illustrates the changes in turbine and generator technology during the brief span of 15 years.

The original Dam 5 plant, placed in operation in 1904, used vertical shaft turbines originally installed around 1890 to provide the mechanical power required for pulp grinding. Adapting these turbines for use in electric generation required using wooden bevel gears and rope drive to transmit the turbines' mechanical power to a 450 kilowatt horizontal shaft generator. Within five years, the Dam 4 plant was completed and equipped with tandem, multi-runner Francis style horizontal shaft turbines. These units, once again, used rope drive to transmit the turbines' mechanical power to 500 kilowatt horizontal shaft generators. A decade later, in 1918, when the second Dam 5 plant was built, vertical shaft turbines, direct connected to vertical shaft generators equipped with roller thrust bearings, proved to be the most efficient, cost effective, and, hence, common equipment used in low head hydroelectric plants.

Limited water rights, irregular flow, and frequent flooding all dictated that the equipment used in the Potomac River hydroelectric plants be capable of reliable performance under erratic, unpredictable, and occasionally severe operating conditions. Consequently, all three Potomac River plants epitomized conservative design and used proven rather than innovative technology.

The continuous operation of the Dam 4 and 5 hydroelectric plants without significant alterations to either the buildings or the equipment gives these two facilities an historic significance that goes far beyond their original contribution to the economic growth and industrial development of the mid-Potomac River Valley. Together, the Dams 4 and 5 hydroelectric plants not only illuminate homes, offices, and factories, but also reveal the significant advances in low head hydroelectric generating technology, engineering, and operations made during a single decade of the early twentieth century.

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Number	Subject
13217	Leffel & Co., "40 Inch Samson Horizontal Turbines.
34736	Leffel & Co., "Proposal for Vertical Wheel."
38366	Leffel & Co., "Vertical Turbine for PEC."
38367	Leffel & Co., "Vertical Turbine for PEC."
38368	Leffel & Co., "Vertical Turbine for PEC."
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1232	Leffel & Co., "Proposal 56 Inch Samson Turbine."
1304	MPC, "Plant Layout."
1304A	MPC, "Detail Sheet."
1304B	MPC, "Elevation Layout."
M-1001-D	PEC, "Leaks Through Dam 4."
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62932	Warren Electric Co., "Generator."
62940	Warren Electric Co., "Shaft-Rotating Field."
62942	Warren Electric Co., "Switchboard."
533	Wolf Co., "Rope Sheave."
556	Wolf Co., "Tension Carriage."

Dam 5 Plant

Sanderson & Porter Drawings

Number	Subject
204-A-1	"Structural Steel for Building."
A-2	"Power Station Substructure."
A-3	"Substructure Reinforcement Details."
A-4	"Steel Reinforcement in Concrete Beams and Floors."
A-5	"33 kV Outdoor Substation."
204-B-1	"Draft Tube Details."
B-2	"Scroll Case."
B-3	"Head Race Wall on River Side."
B-4	"Structural Steel Details."
B-6	"Concrete Piers at Entrance to Head Race."
B-9	"Detail of Penstock Head Gates."
B-10	"Penstock Head Gates and Operating Mechamisms."
B-11	"Horizontal Racks at Entrance to Head Race."
B-12	"Trash Racks and Beams in Head Race."
B-13	"Architectural Details: River-Downstream Elevations."
B-14	"Architectural Details: Shore-Upstream Elevations."
B-15	"Architectural Details."
B-16	"Concrete Piers for Trash Racks."
B-20	"Car for Operating Head Gates (Stop Logs)."
B-21	"Switchboard, Front View."
B-22	"Steel Work, Outdoor Substation."
204-C-5	"Governor and Auxiliaries with Piping."

C-6	"Window Diagram."
C-7	"Stop Logs at Entrance to Scroll Case."
C-9	"33 KV Outdoor Substation."
C-10	"Proposed 22 kV Substation at Martinsburg."
C-11	"Flashboards at Dam No. 5."
204-D-7	"Concrete Top with Flashboards."
204-RA-2	"General Plan of Power Station."
	"Sketch Design for Superstructure, Dam 5 Plant."

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6234	Diamond Iron Works, "Flywheel."
3770	EM, "Thrust Bearing Assembly."
3783	EM, "Vertical Type Alternator."
24925	Leffel, "General Arrangement, 51 Inch Z Turbine."
25065	Leffel, "General Arrangement, 51 Inch Z Turbine."
25066	Leffel, "Section Assembly, 51 Inch Z Turbine."
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