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S. MORGAN SMITH COMPANY

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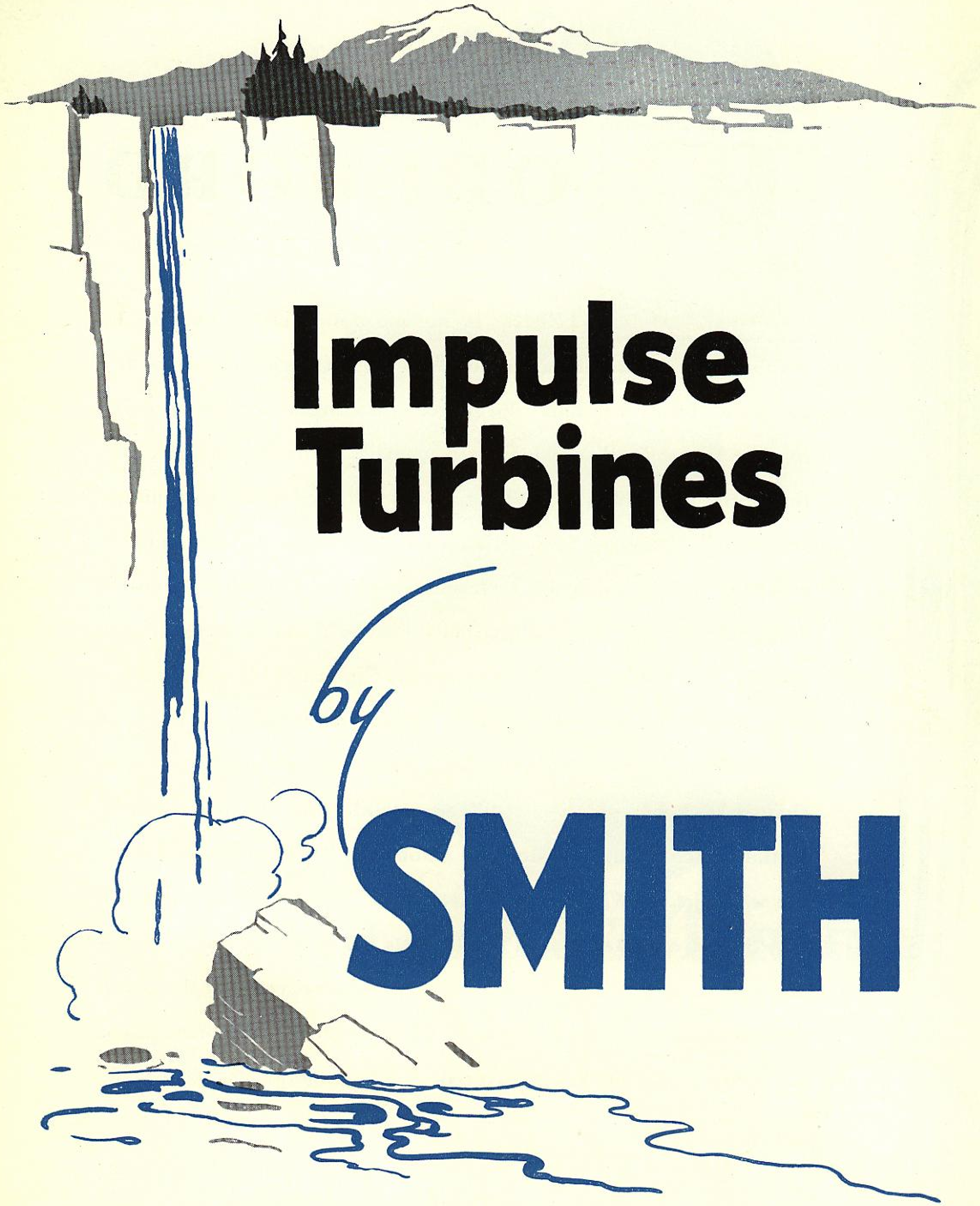
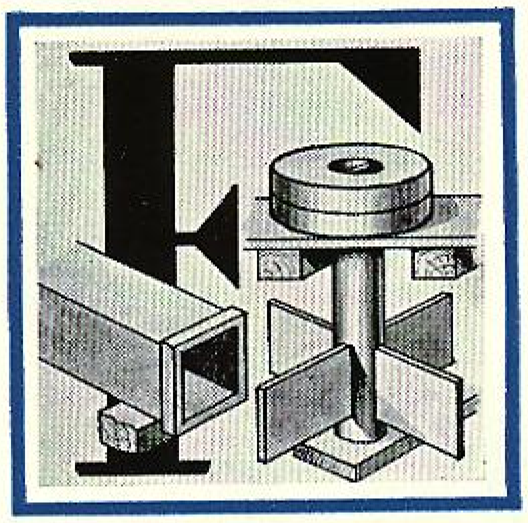
POWER IMPULSE TURBINES by SMITH



Impulse Turbines

by

SMITH



FOREWORD

THERE is no more interesting chapter in man's battle with natural forces than the one which records his conquest of water. ¶ Early did he recognize that water, always seeking the lowest level, created motive power by its own weight, and that when it was flowing at high velocity it developed a continuous source of energy. ¶ Seeing this energy available he originated a means of transforming this hydraulic energy into useful mechanical energy by having the high velocity stream strike a series of flat paddles attached to an axle and thus the Impulse Turbine came into existence. ¶ But the gold miners of '49 were the real progenitors of the modern impulse turbine. They developed hemispherical cup shaped buckets with the jet of water striking the buckets squarely in the center thus increasing the amount of power recovered from the water jet. ¶ When a wheel accidentally slipped on its shaft one day the jet of water struck the buckets on one edge and was discharged from the other side. The operator observed that the wheel picked up in power and speed. In this manner was the principle of the modern split bucket discovered.

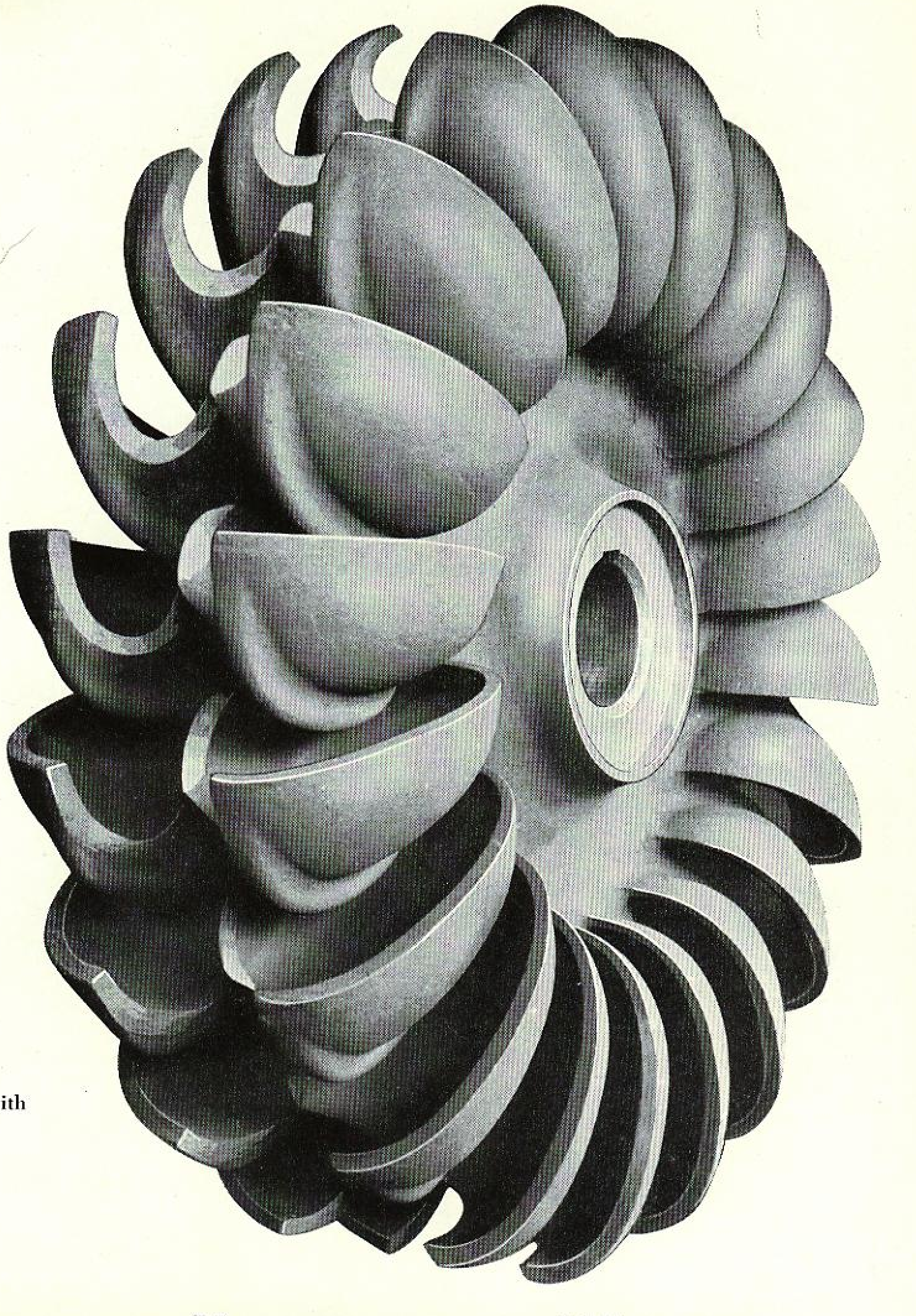


Fig. 1: Close-up of Smith Impulse Runner.

The SMITH *IMPULSE* TURBINE

SMITH'S principal contribution to the art of building Impulse Turbines is the new-design of high speed runner which reaches specific speeds up to 10 and still maintains high efficiencies over a wide load range.

This result has been obtained in Smith Impulse Turbines by utilizing a solid-cast runner which permits the use of a greater number of buckets, more closely spaced than was ever possible with the old design consisting of separate buckets bolted to the runner disc, commonly used until Smith introduced the solid-cast runner which set new all-time highs in both speed and efficiency. Incidentally, due to the higher operating speed of the Smith runner a smaller turbine and generator can be used, resulting in a decided reduction in the over-all cost of equipment.

A very marked advantage of the Smith design is the scientifically correct location and proportions of the fixed nozzle so designed as to obtain a clear jet and minimum loss. Consequently the full force of the jet of water impinges properly on each bucket as the runner rotates. Thus energy is saved, efficiency increased and greater freedom from cavitation and erosion is assured.

In addition, due to proper baffling inside the housings the water discharges freely from Smith Impulse Wheels with a minimum of loss, and absence of vibration and noise.

Another Smith feature is the design of buckets which are so shaped that the maximum energy of the water is utilized. Qualities of materials used in both bucket and nozzle castings are contributing factors to the reputation for low maintenance costs Smith Impulse Turbines enjoy. This strict adherence to high standards combined with proper design of buckets and nozzles afford maximum resistivity to wear.

Exhaustive tests in the Smith Hydraulic Laboratory, confirmed by actual field results, assure high efficiencies to users of Smith Impulse Turbines.

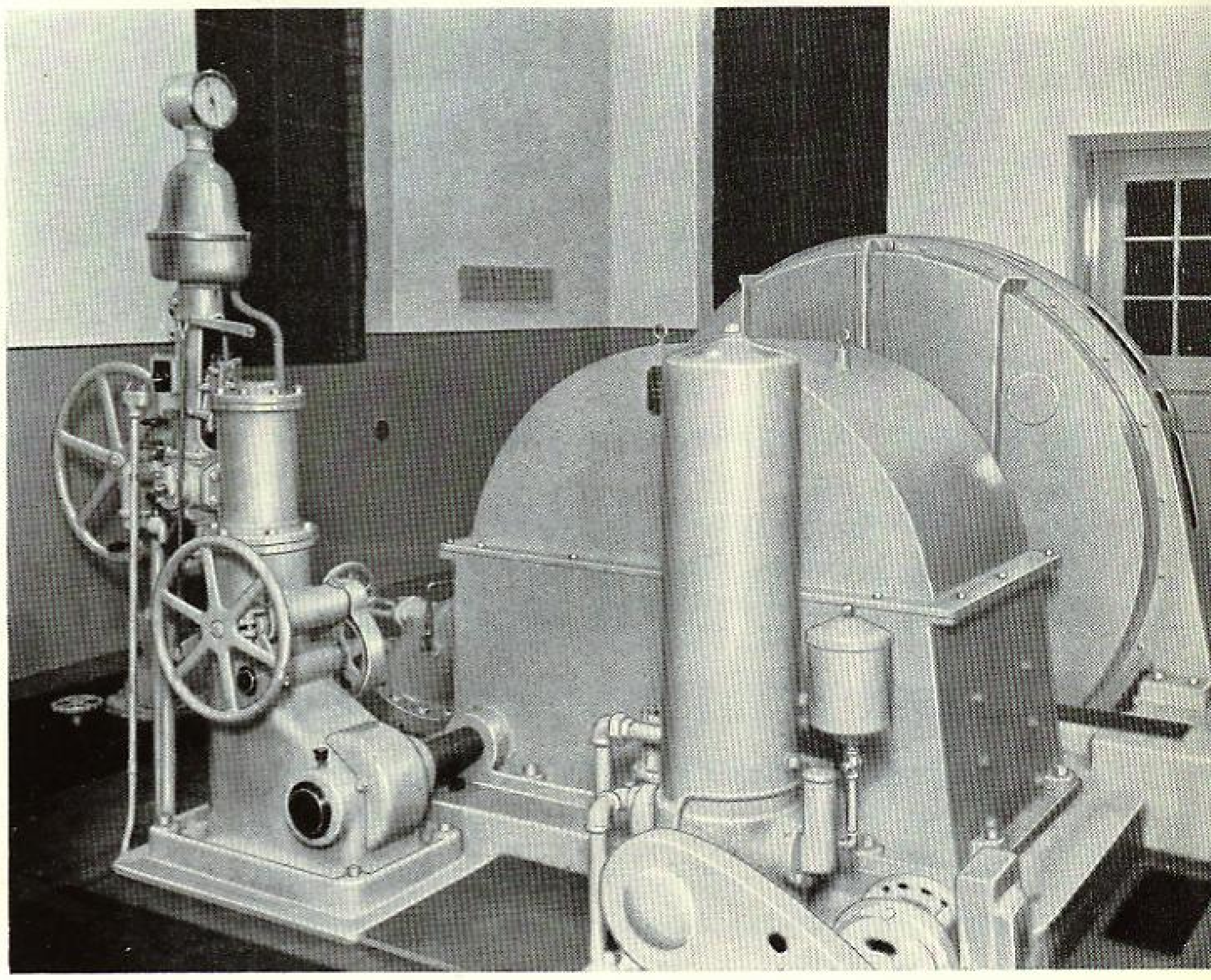


Fig. 2: View of Smith Impulse Turbine installed for City of Murray, Utah.

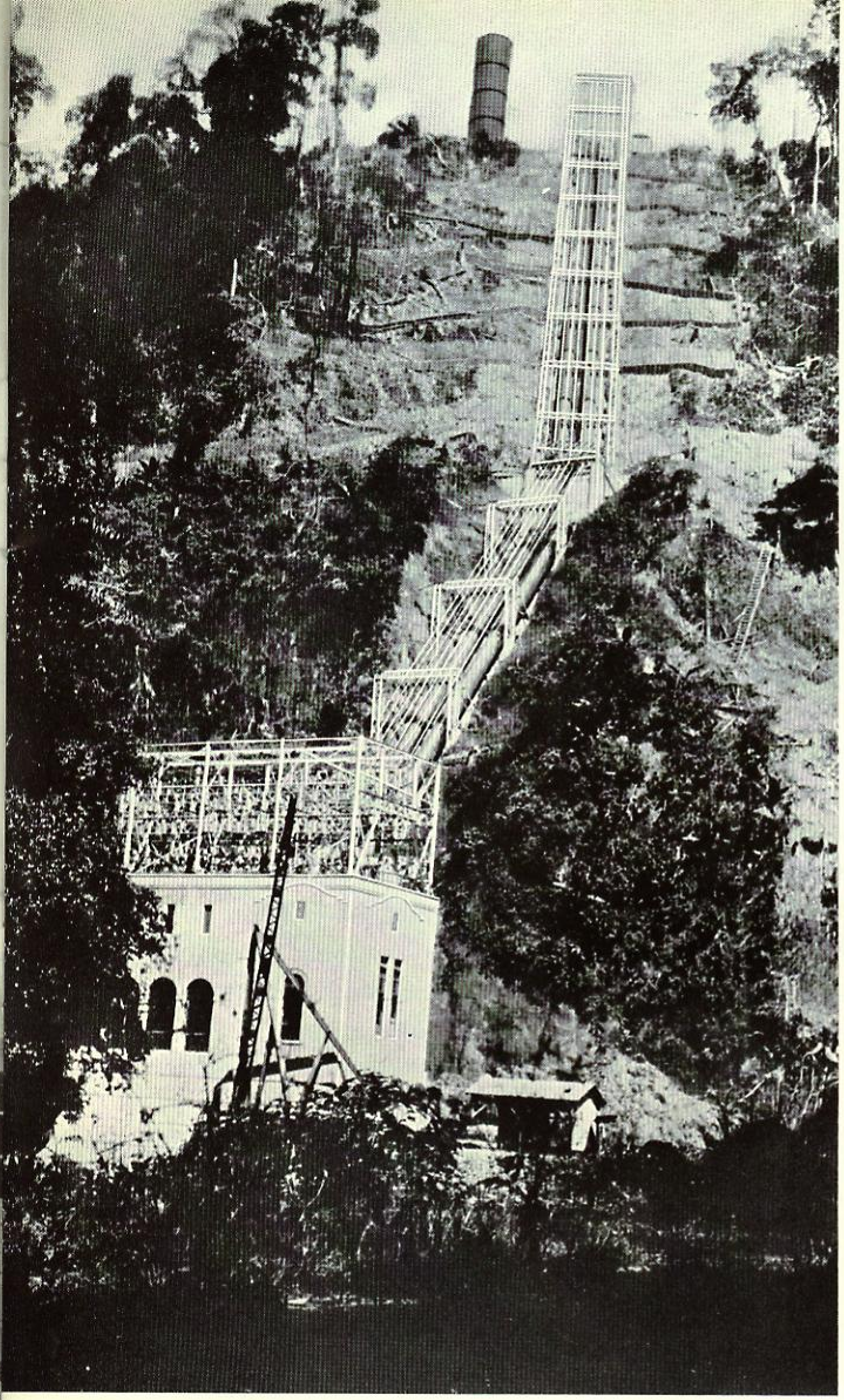


Fig. 3: Representative setting for an Impulse Turbine—a Smith installation developing 1200 H. P., under a 600 foot head in the Philippines.

For High Head PROJECTS

THE IMPULSE, or tangential turbine as it is sometimes called, is primarily a high head, low specific speed unit. As such it has a very definite place in modern, hydro-electric plants and must be used wherever the head and water quantities available prohibit the use of reaction-type turbines, and is ideal for installations in remote places where the simplicity of the impulse design, the ease with which the completed unit may be transported, and its dependability are advantages which no other type of turbine can provide.

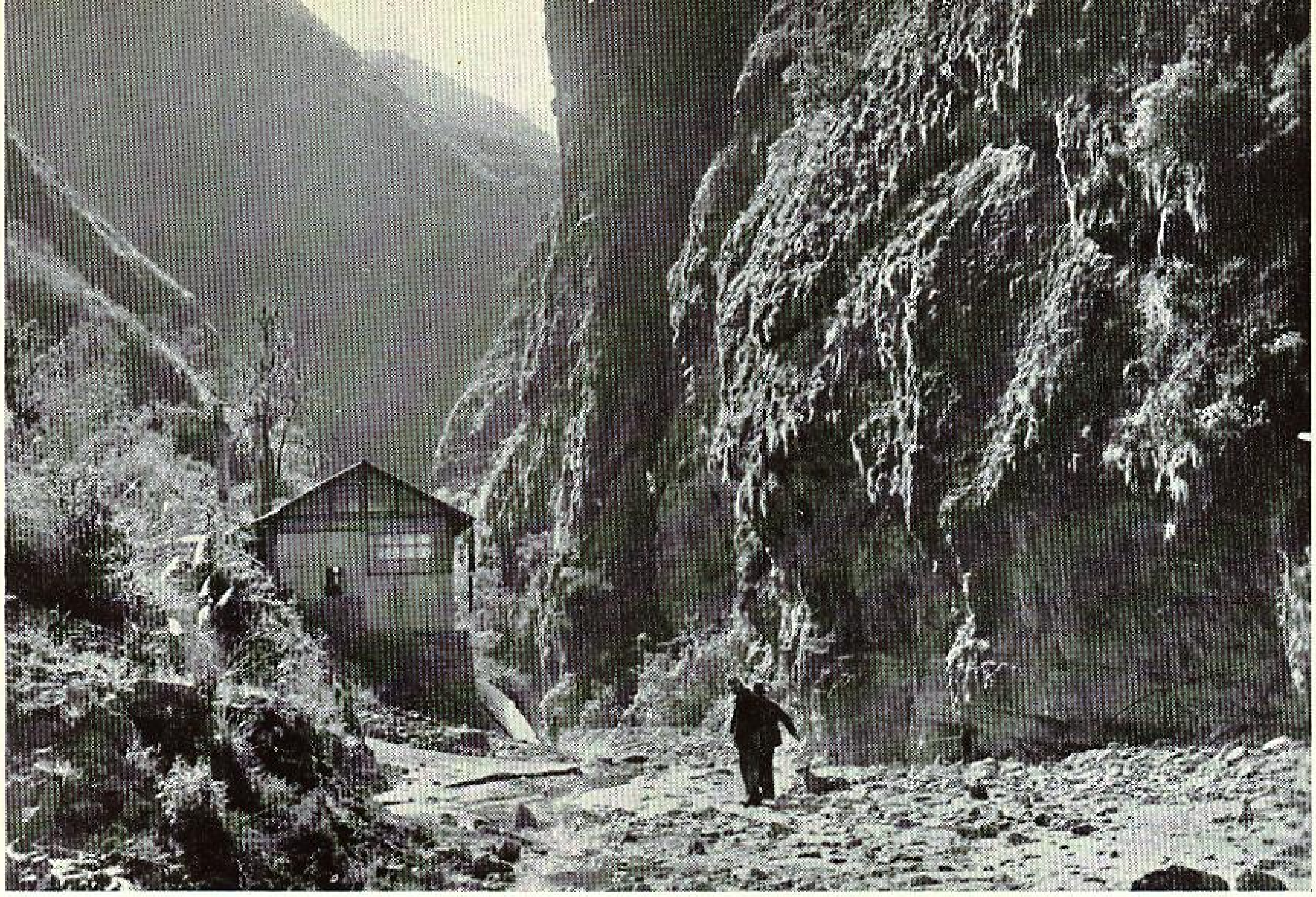
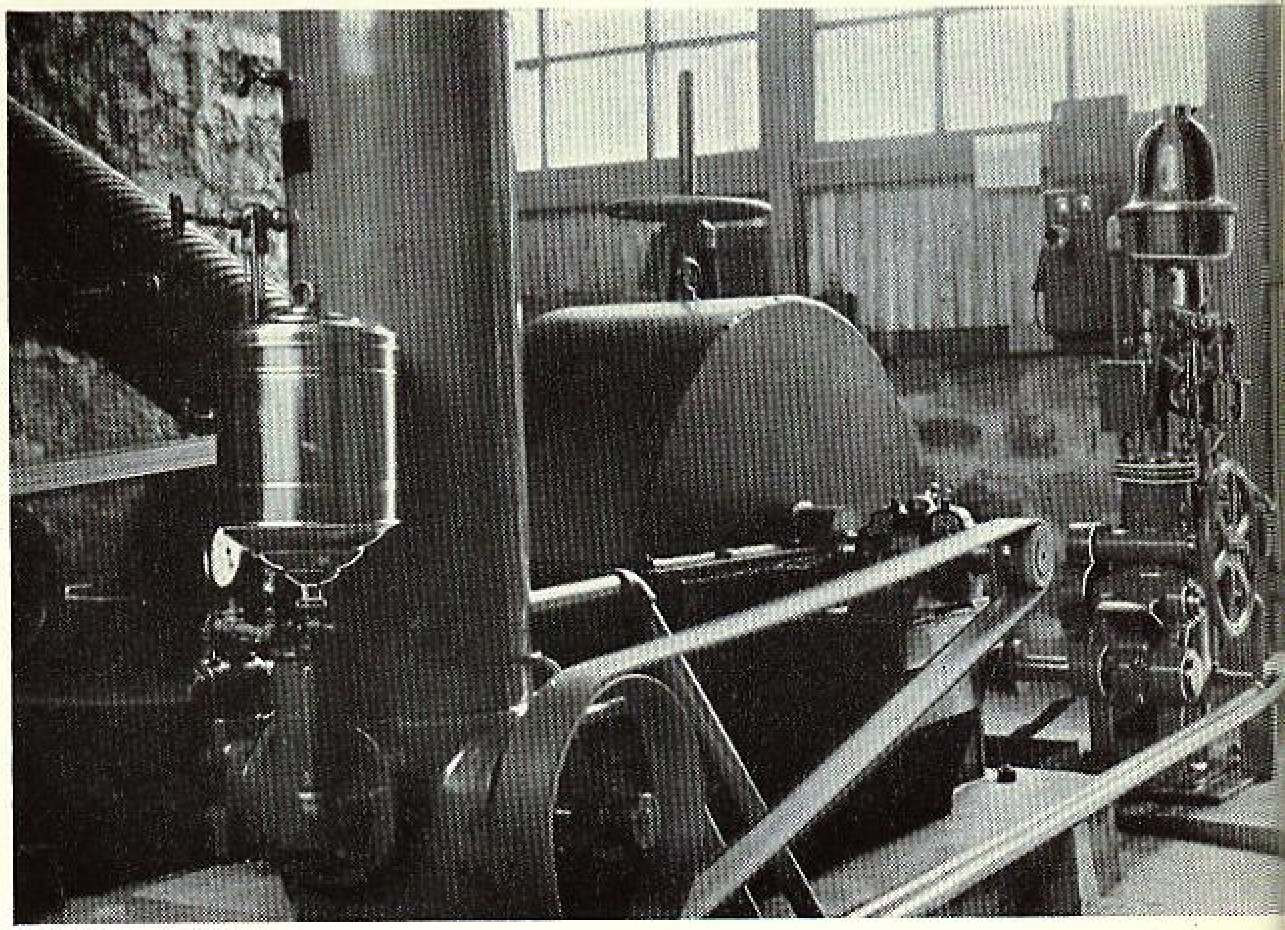


Fig. 4: Scene showing that Power by Smith can be produced anywhere.

In fact, due to their higher efficiencies and ability to sustain these high efficiencies much longer than high head reaction turbines, because of wear, Smith Impulse Wheels are very definitely invading the upper head range field of reaction turbines.

Impulse Turbines, because of their adaptability for high heads, are usually located in mountainous regions where accessibility and transportation problems are major factors. Under these conditions the quality and design of the impulse turbine assume tremendous importance. That is why Smith Impulse Turbines have been so widely adopted. Their simplicity, reliability, and ease of operation obviate any necessity for skilled operators or attendants. These qualities plus low maintenance costs, together

Fig. 5: Interior of power house above with turbine in the center.



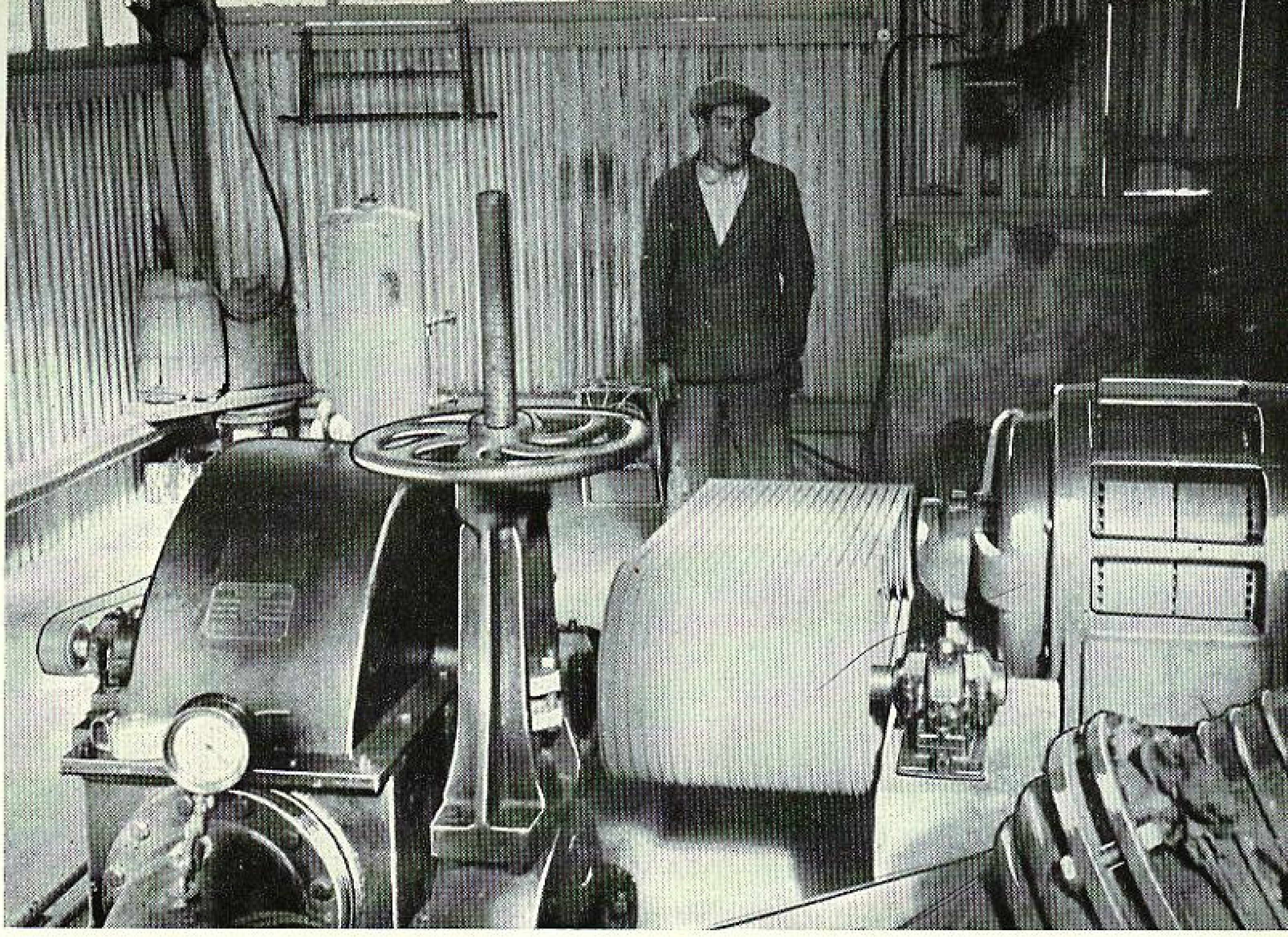


Fig. 6: Smith Impulse Turbine driving a generator through V-type belts.

with their greater speed and higher efficiency, constitute vitally important advantages to users—particularly essential to those who operate in sections difficult to reach and where service facilities are very limited.

These views of a small Smith installation in Chile show what can be accomplished. The instance is by no means rare—just typical of many that could be shown of Smith installations in the United States and in Foreign Countries. These users, today, by reason of the Smith High Speed Runner, permitting higher specific speeds without sacrifice of high efficiency, are enjoying extremely marked advantages and important benefits which before its introduction were unavailable.

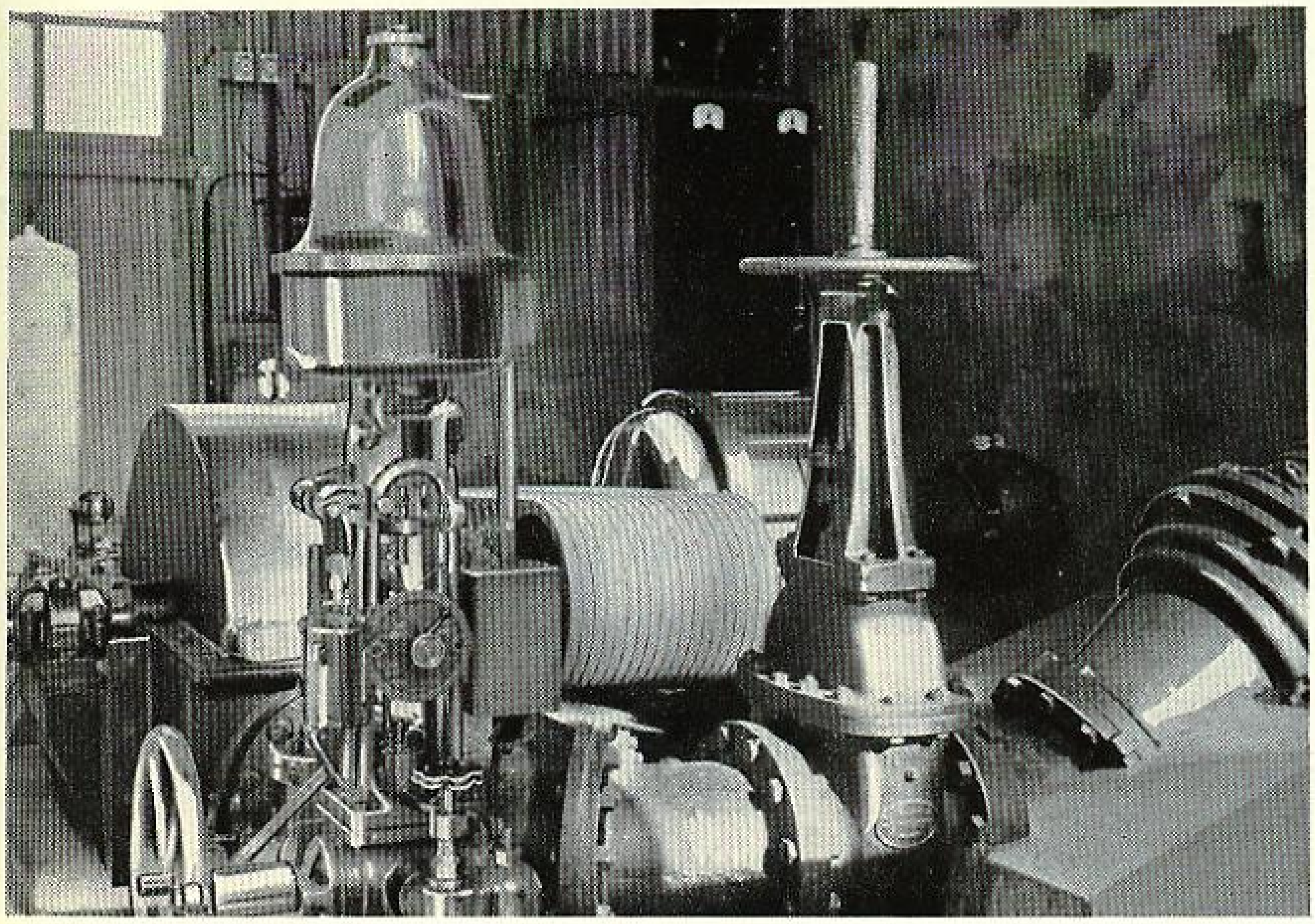
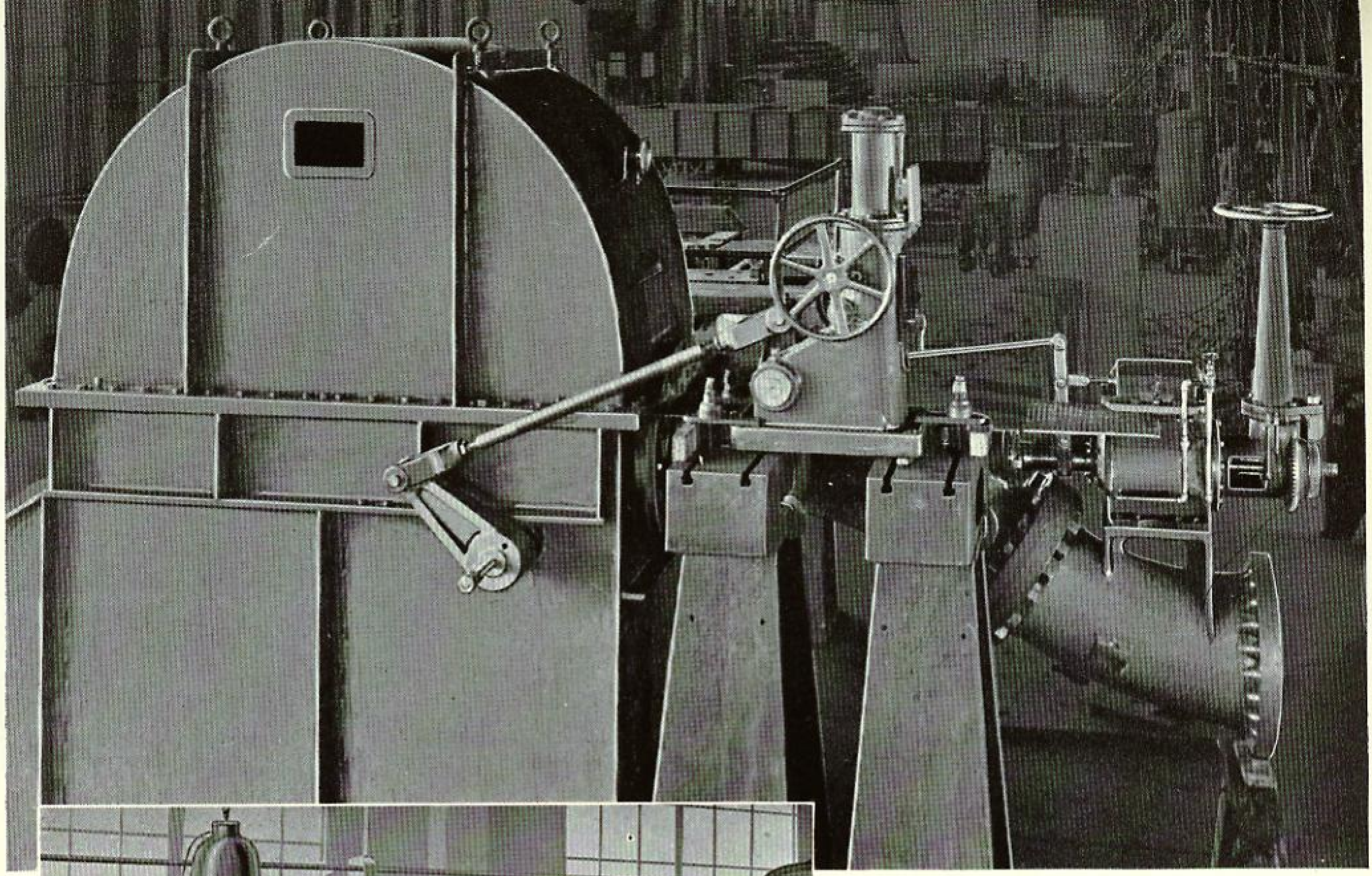
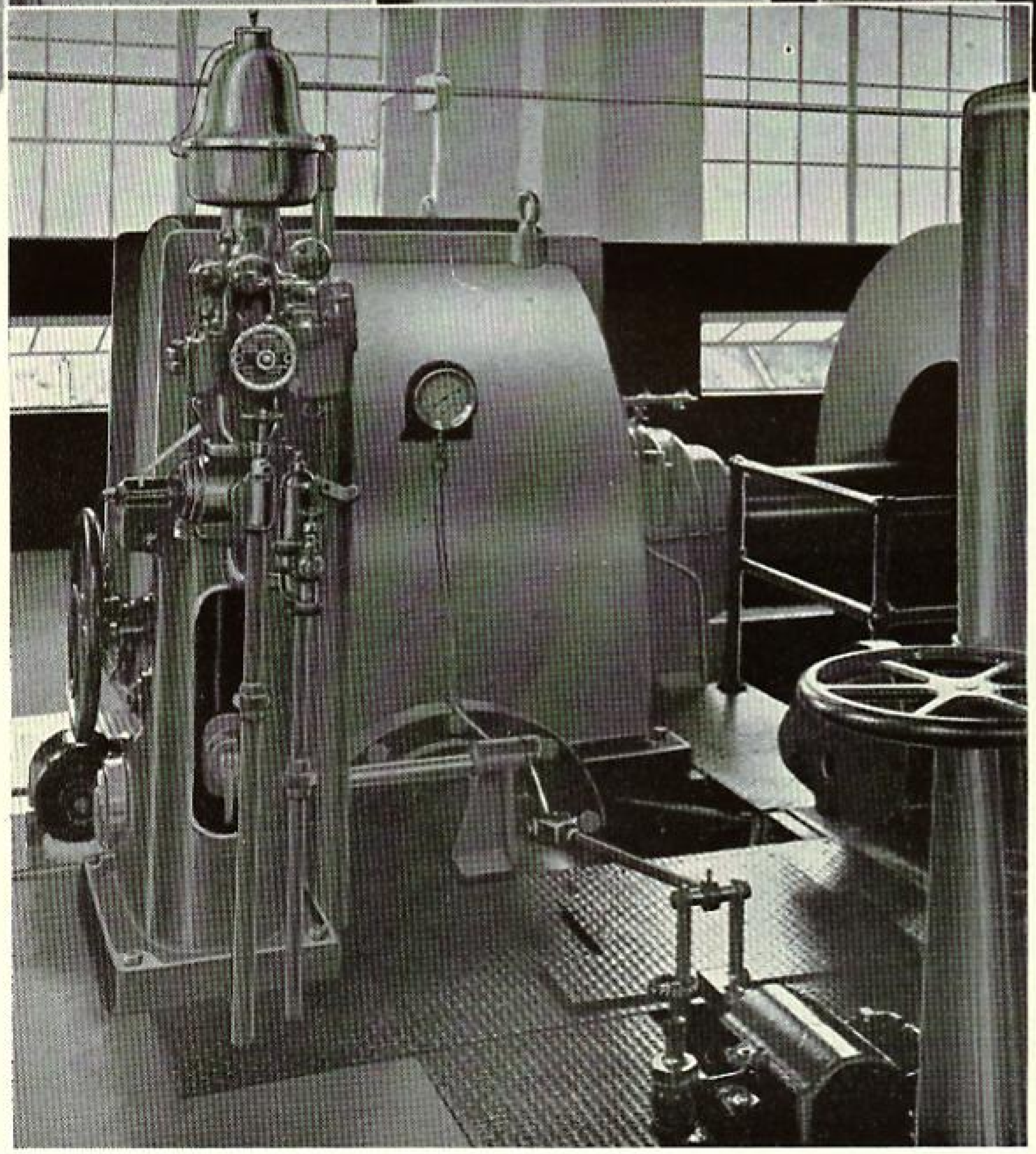


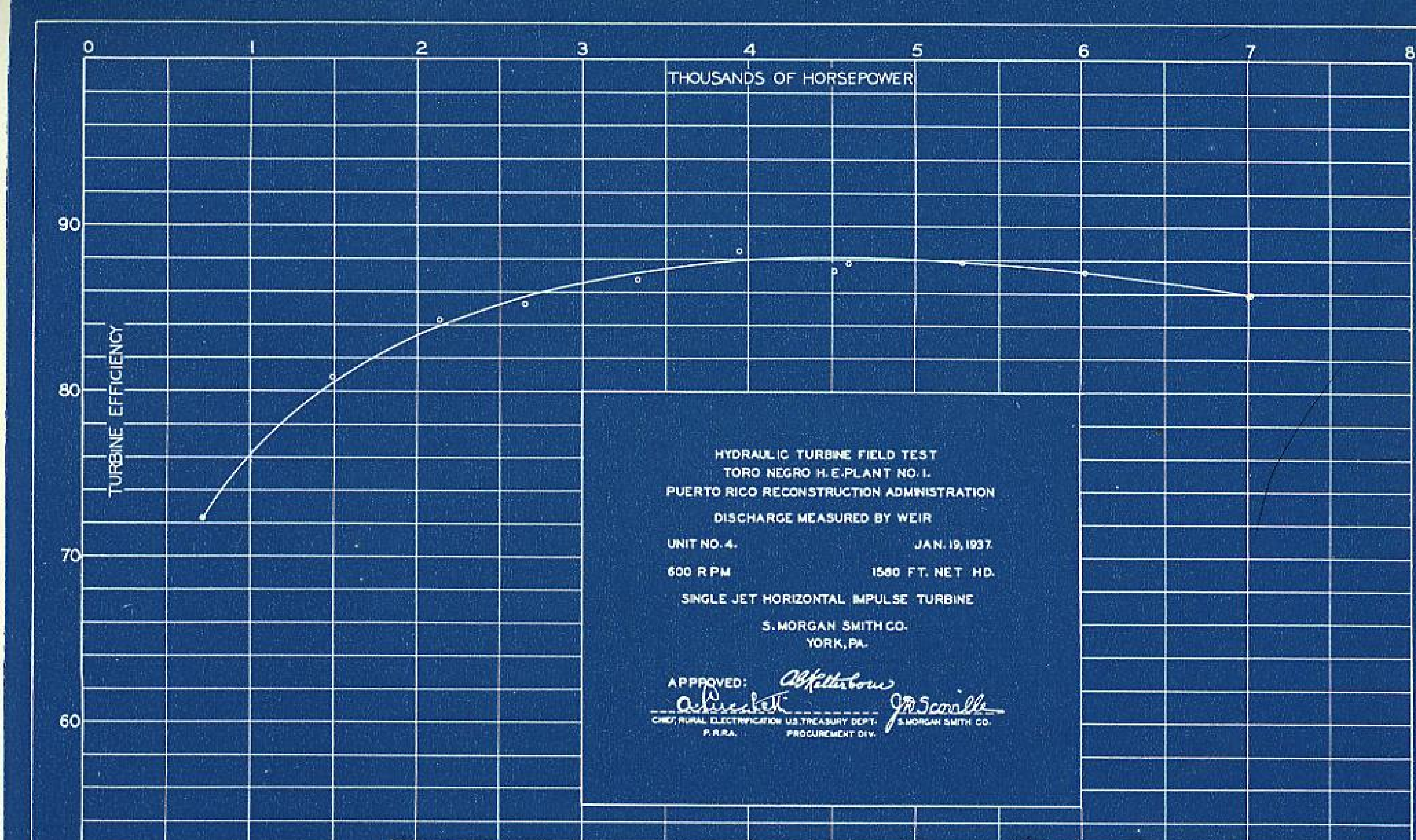
Fig. 7: Compactness of design well illustrated in this Smith installation.





THE installation in this modern power house, Toro Negro No. 1, recently completed by the Puerto Rico Reconstruction Administration, is particularly interesting because waste of water is eliminated by the Smith design.

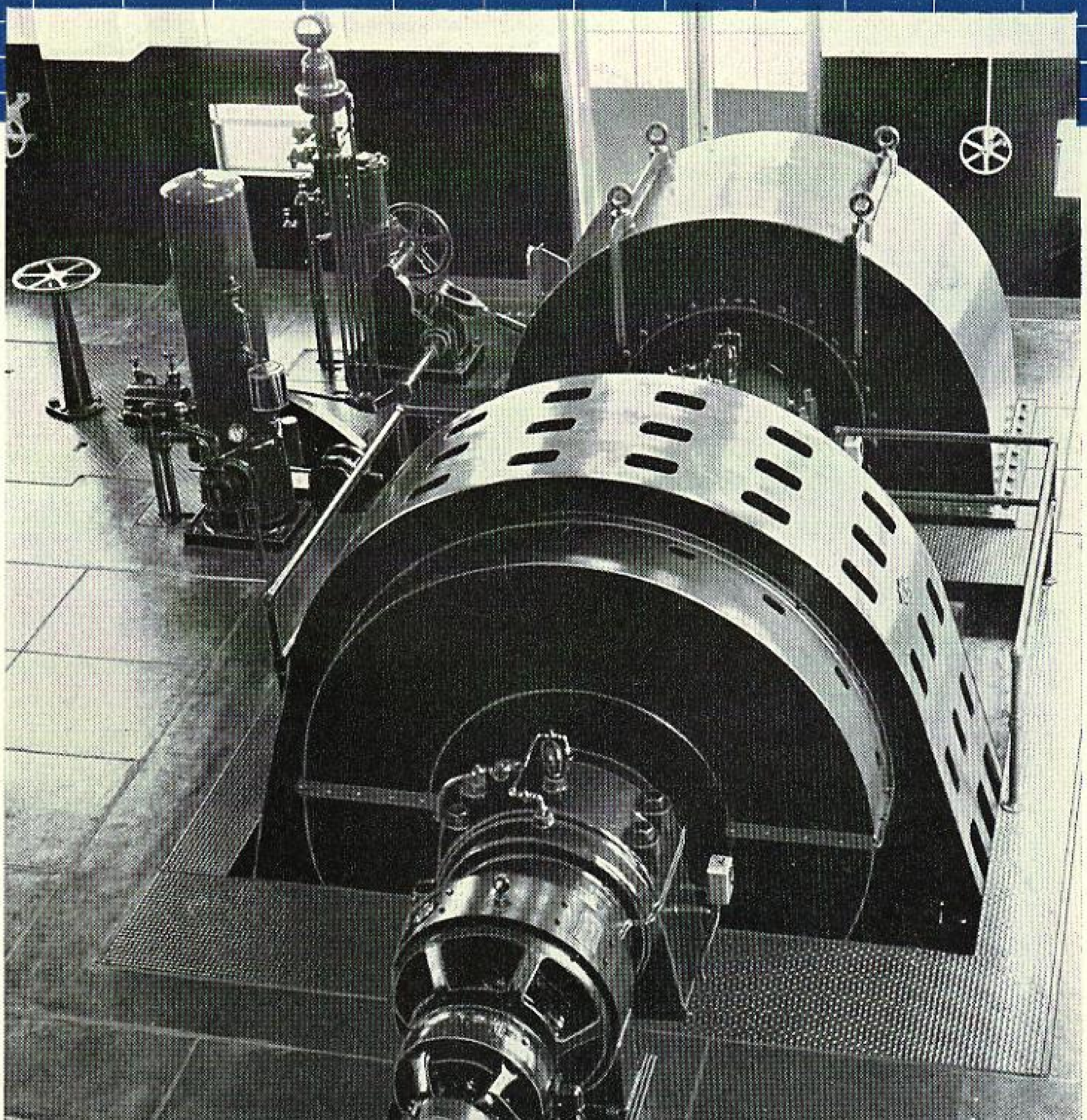
This turbine is closely regulated by a governor operated deflector and power needle nozzle which act together, automatically, as the load changes. When the load is thrown off the deflector moves rapidly into the jet deflecting a portion of the jet from the buckets sufficient to compensate for the reduced load. The needle then slowly closes the nozzle opening to the required area and



the deflector returns to its original position. This dual method of regulation prevents water hammer and water wastage.

The single jet, single overhung runner, horizontal shaft, 7000 H. P. Smith Impulse Turbine shown here operates at 600 R. P. M. under a net effective head of 1580 feet.

In order to determine actual performance characteristics this unit was carefully field tested with results shown in the Chart above. As is generally true of all Smith turbines this unit exceeded the guaranteed power and efficiencies by the anticipated margins.



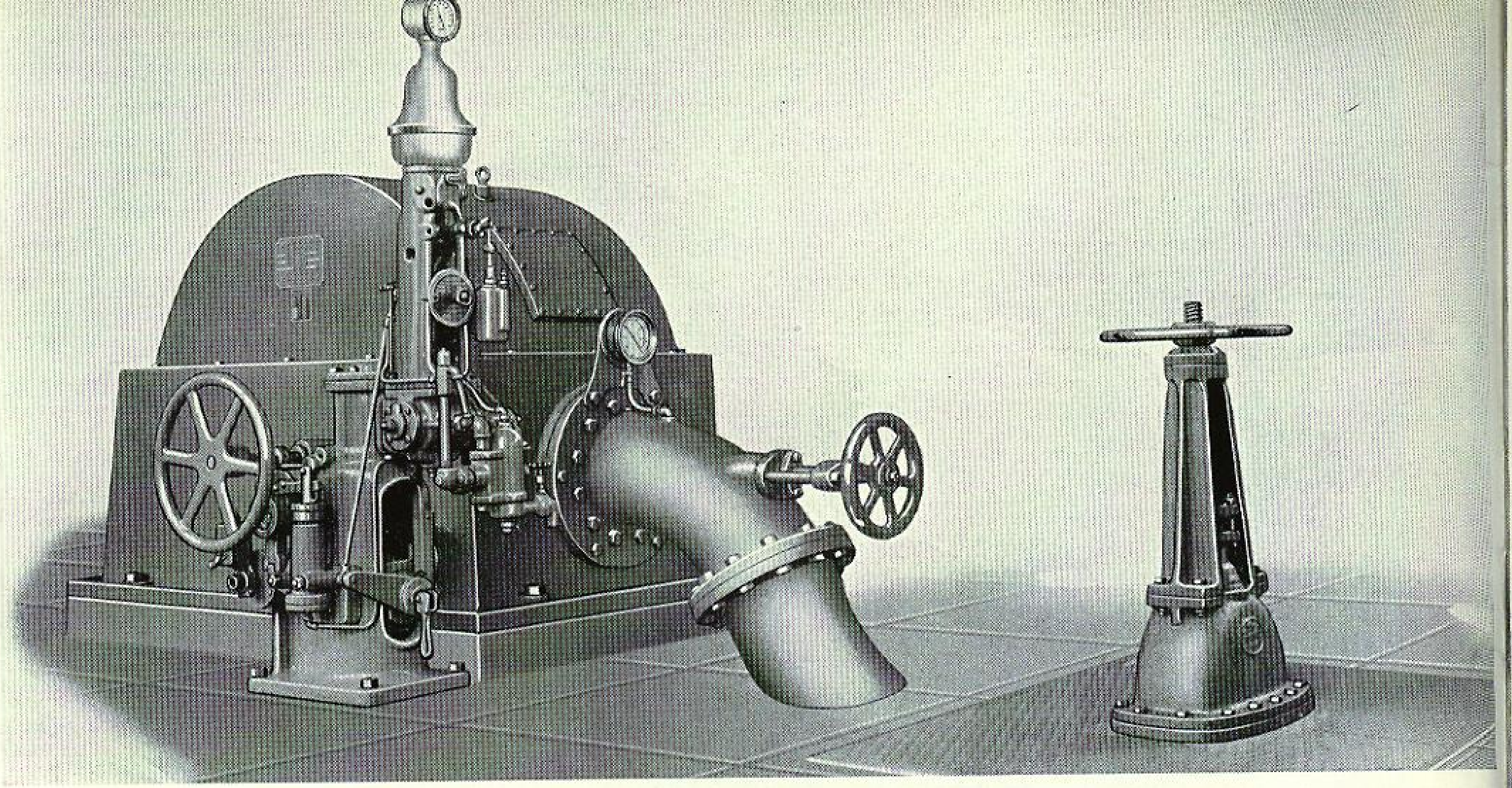


Fig. 8: Typical installation for small and medium capacity units—governor operated jet deflector with manually controlled needle. Governor as shown is equipped with automatic starting mechanism.

Adaptability

ALTHOUGH the Impulse Turbine is essentially a high head wheel, it can be effectively used for low heads, providing the flow of water is small in relation to the head available.

But even where the ratio of water quantity to the head is relatively large an impulse turbine can still be used by adopting a multiple jet or multiple runner design or a combination of these types.

Consequently, impulse turbines are adaptable over a much wider range of heads than other types of turbines. The Chart, Fig. No. 9, shows the general range of specific speeds for each type of hydraulic turbine, and the relationship of speed to head for single jet impulse turbines of various capacities.

Extreme care is necessary in designing and building impulse turbines to produce best performance in service. The number of buckets and their size and angle, correct design for nozzle, needle and jet, the size and design of the housing, position of water baffles, and the proper point of the jet's impact on the runner bucket, must all be determined in advance.

Because of these rigid requirements every care is exercised in assembling data, designing and on through fabrication of the completed units. As evidence of this painstaking attention to detail it should be noted that a model of each Smith High Speed Runner Bucket is designed, built and tested before it is approved for commercial use.

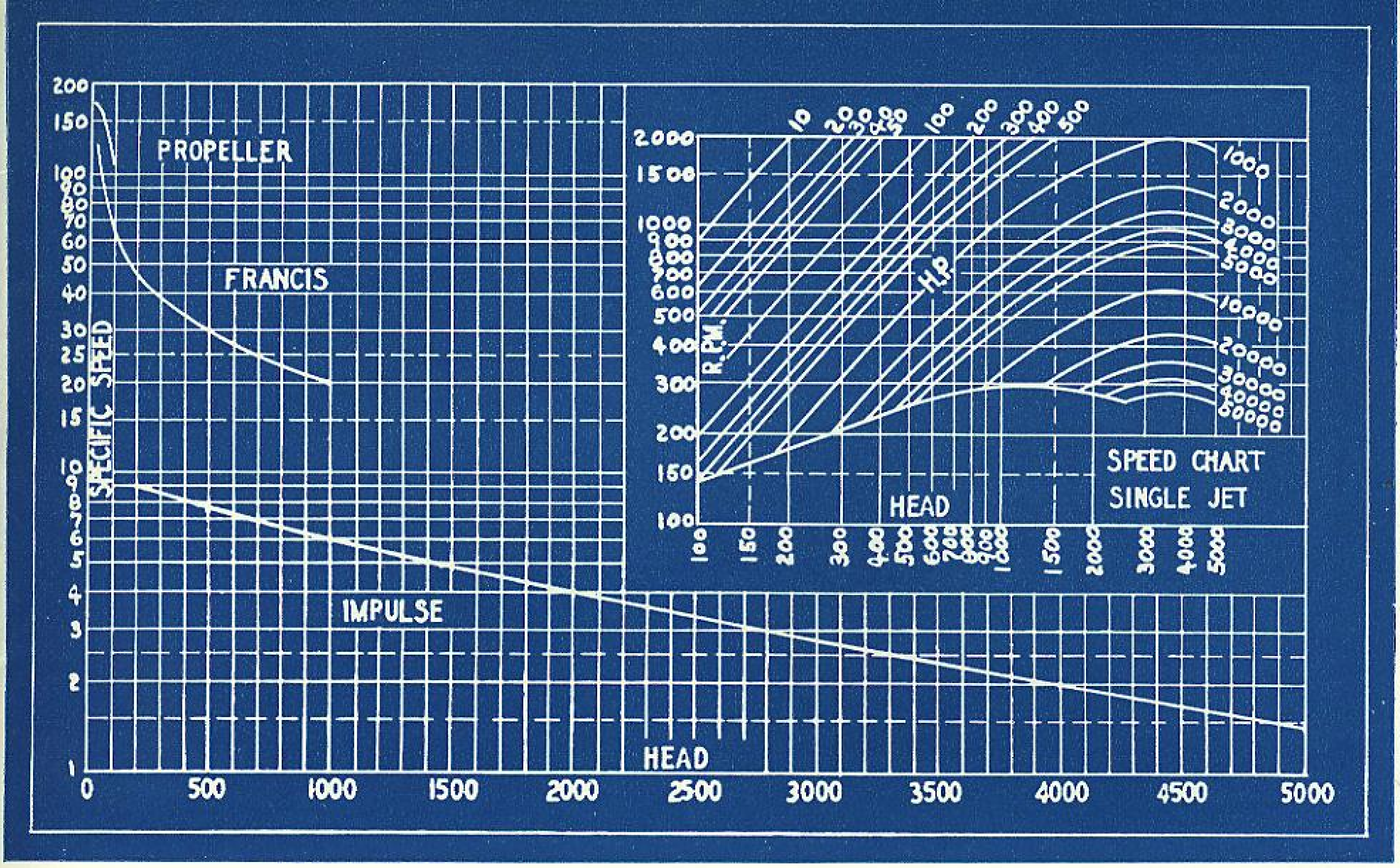
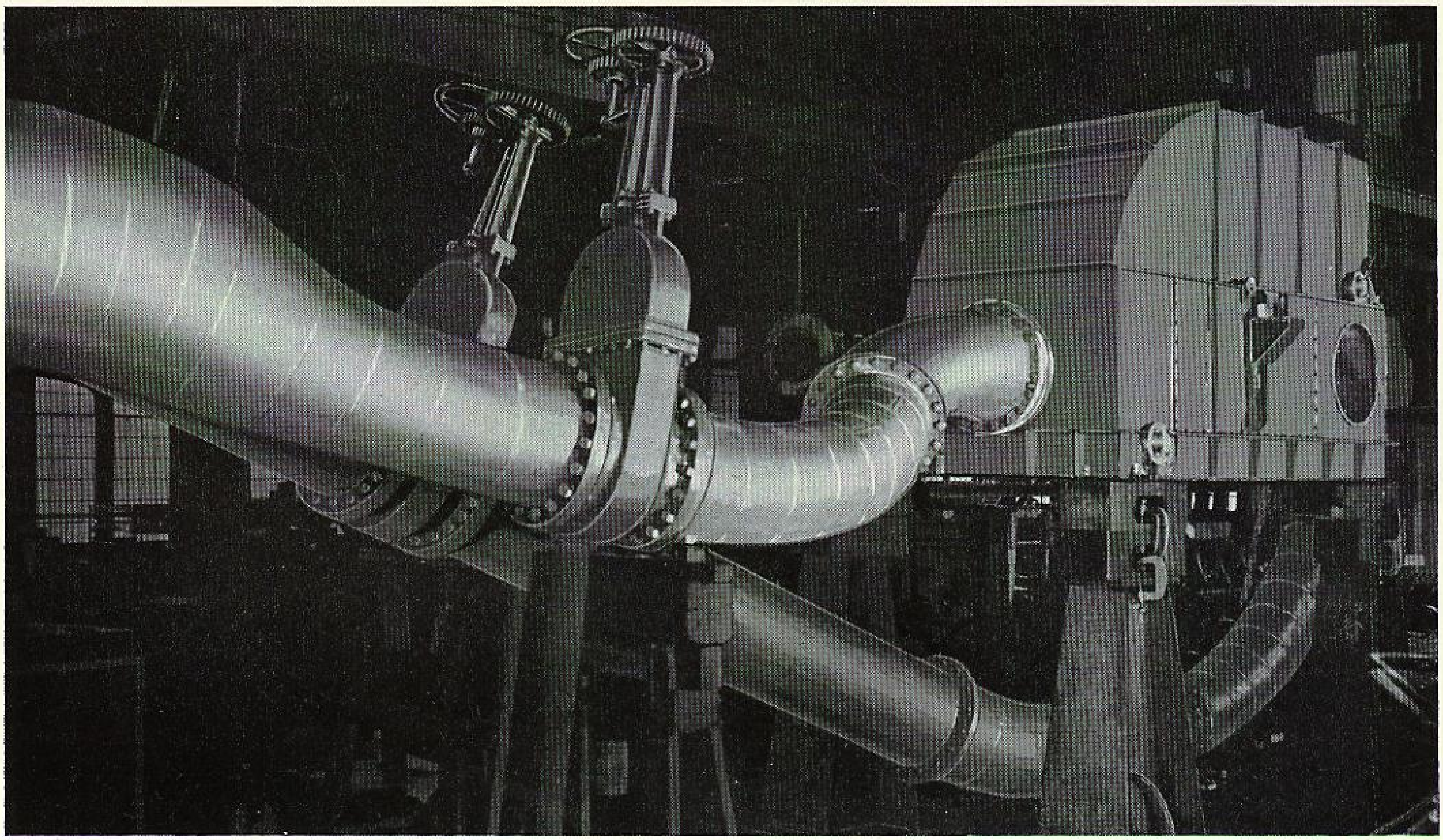


Fig. 9: Chart of generally used specific speeds at various heads—with insert showing approximate speeds for various capacity impulse turbines under different heads.

Fig. 10: Double jet single runner 1570 H. P. turbine operating at 257 R. P. M. under 216 feet head. This unit replaced an old turbine in a plant where maintenance costs had been excessive because of erosion due to abrasive sand carried in the water. Special steel alloys were used in connection with the new Smith design and this unit has now been operating satisfactorily for several years without replacement of parts which before had to be renewed periodically.



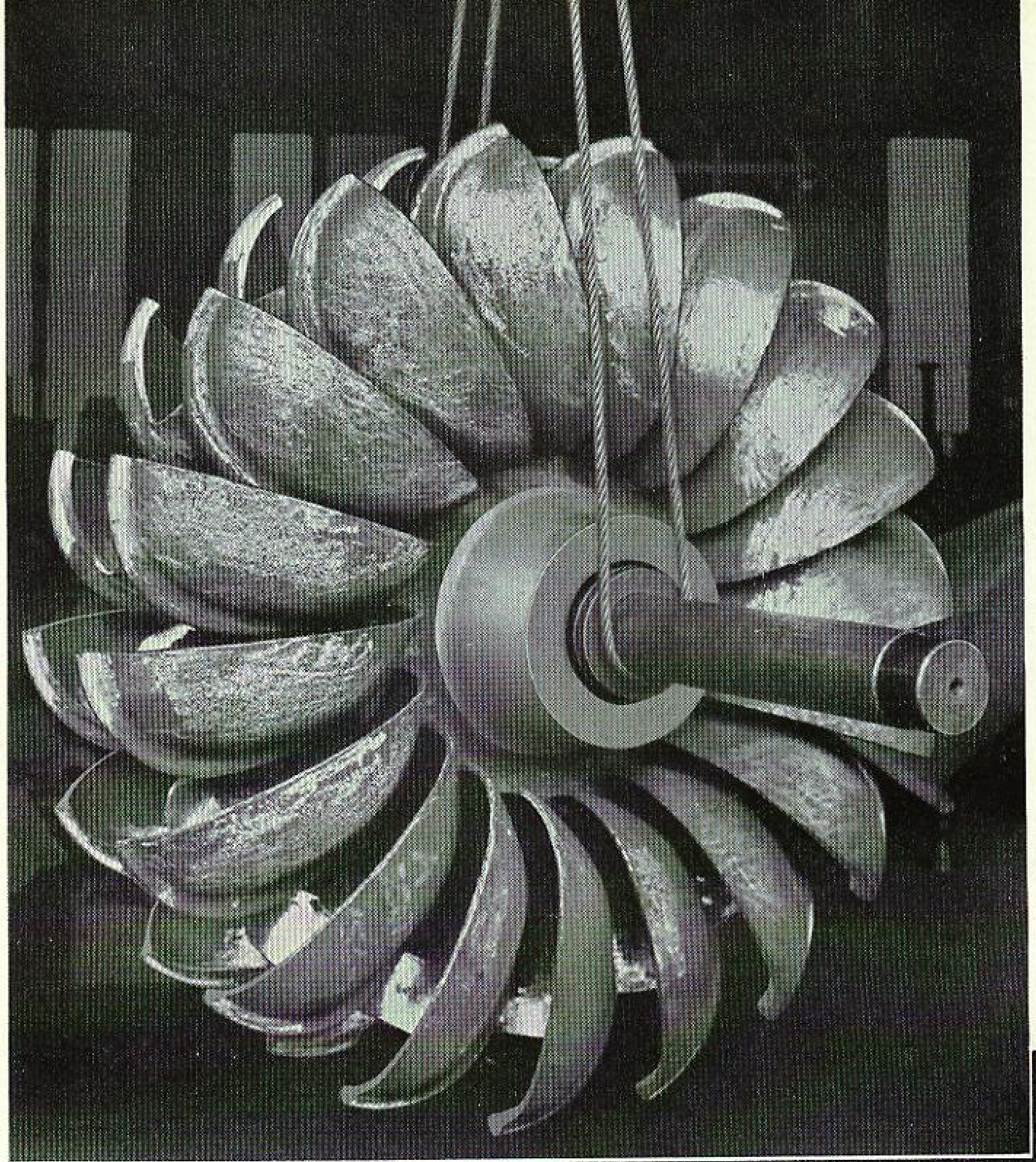
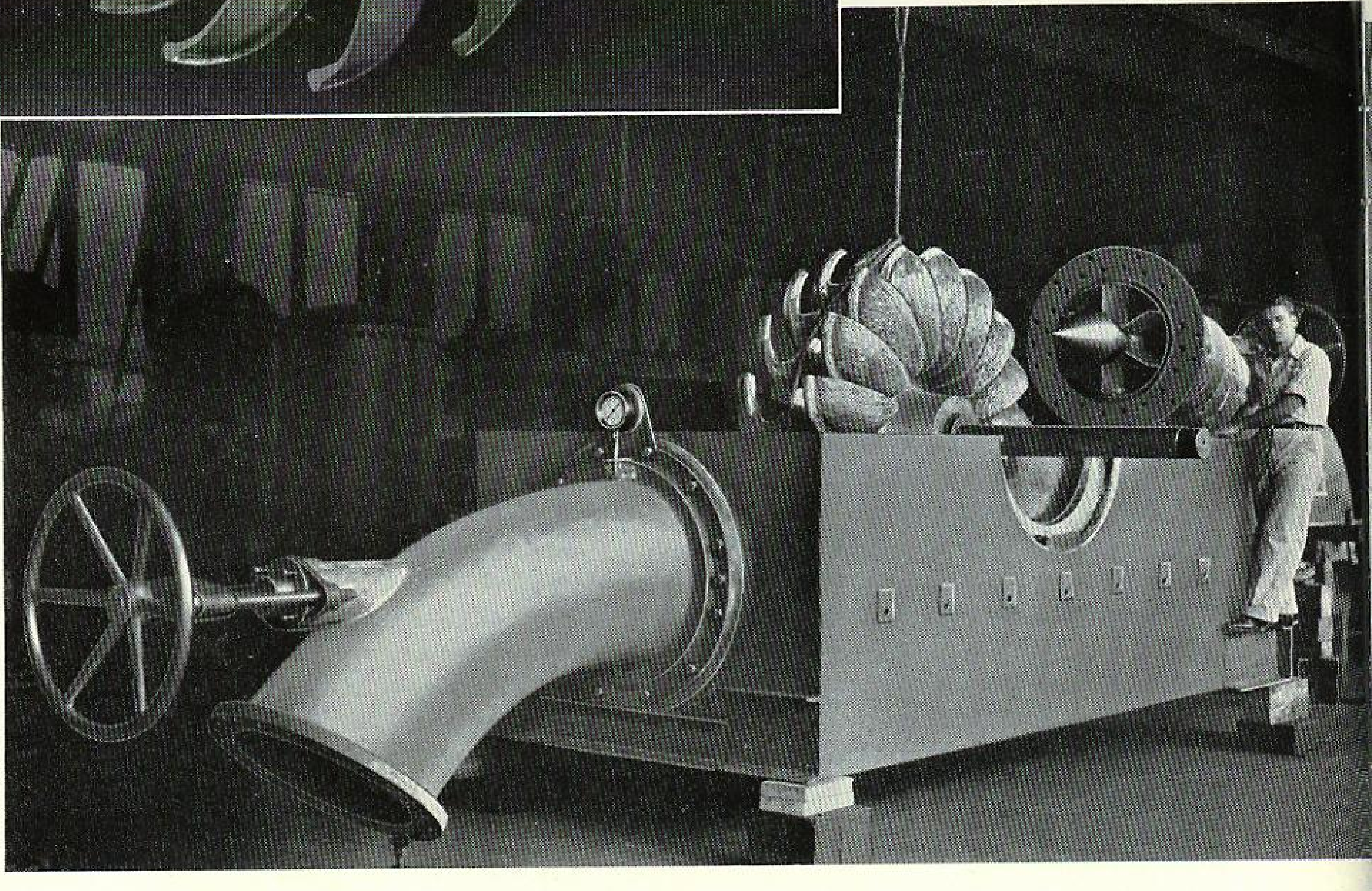


Fig. 11: Runner built for installation in the plant of the Caramanta Mining Company, Colombia, S. A. This unit develops 2500 H. P. at 327 R. P. M. with two jets under a head of 280 feet.

Fig. 12: Shop assembly of runner and power needle nozzles.



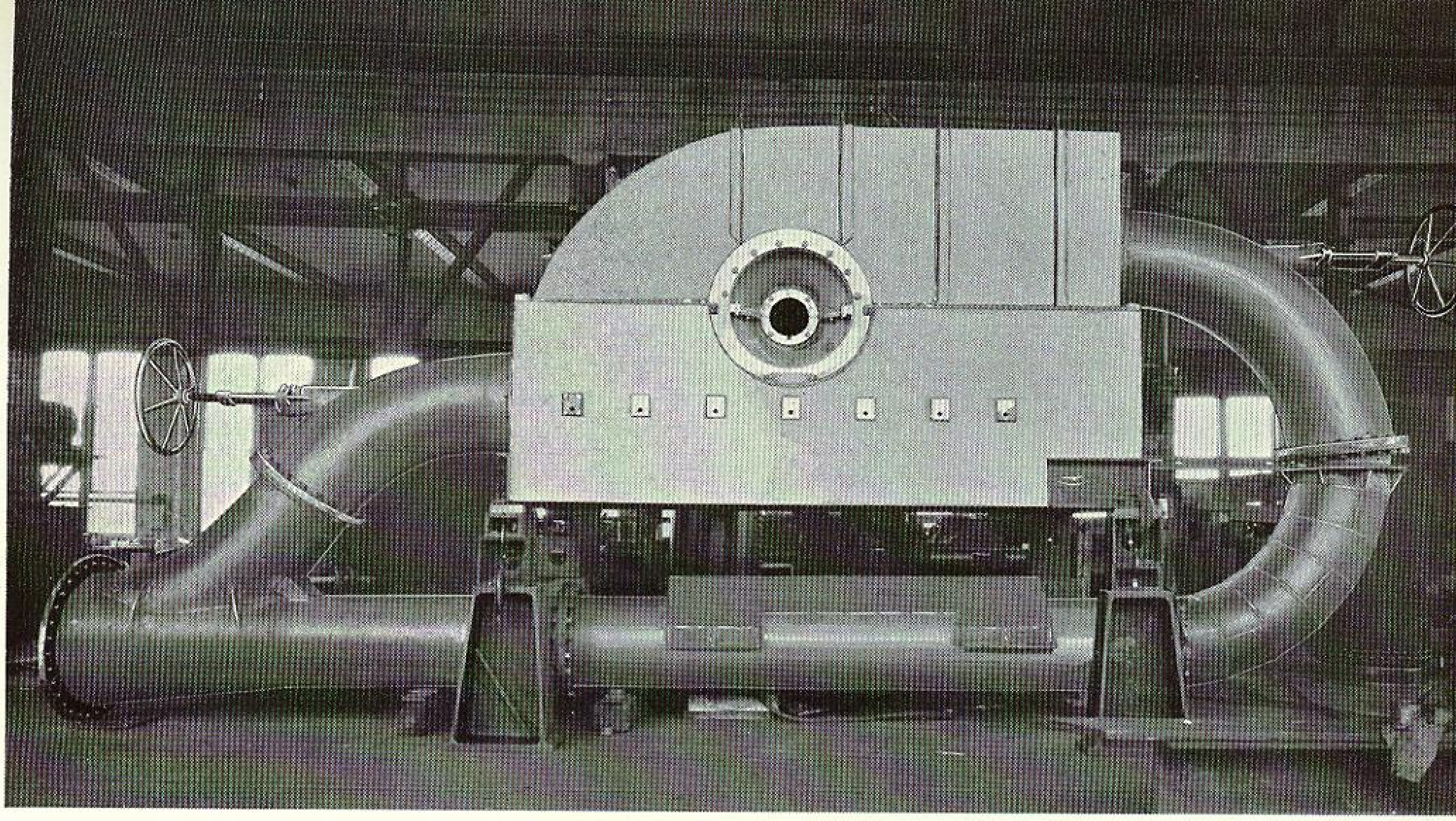
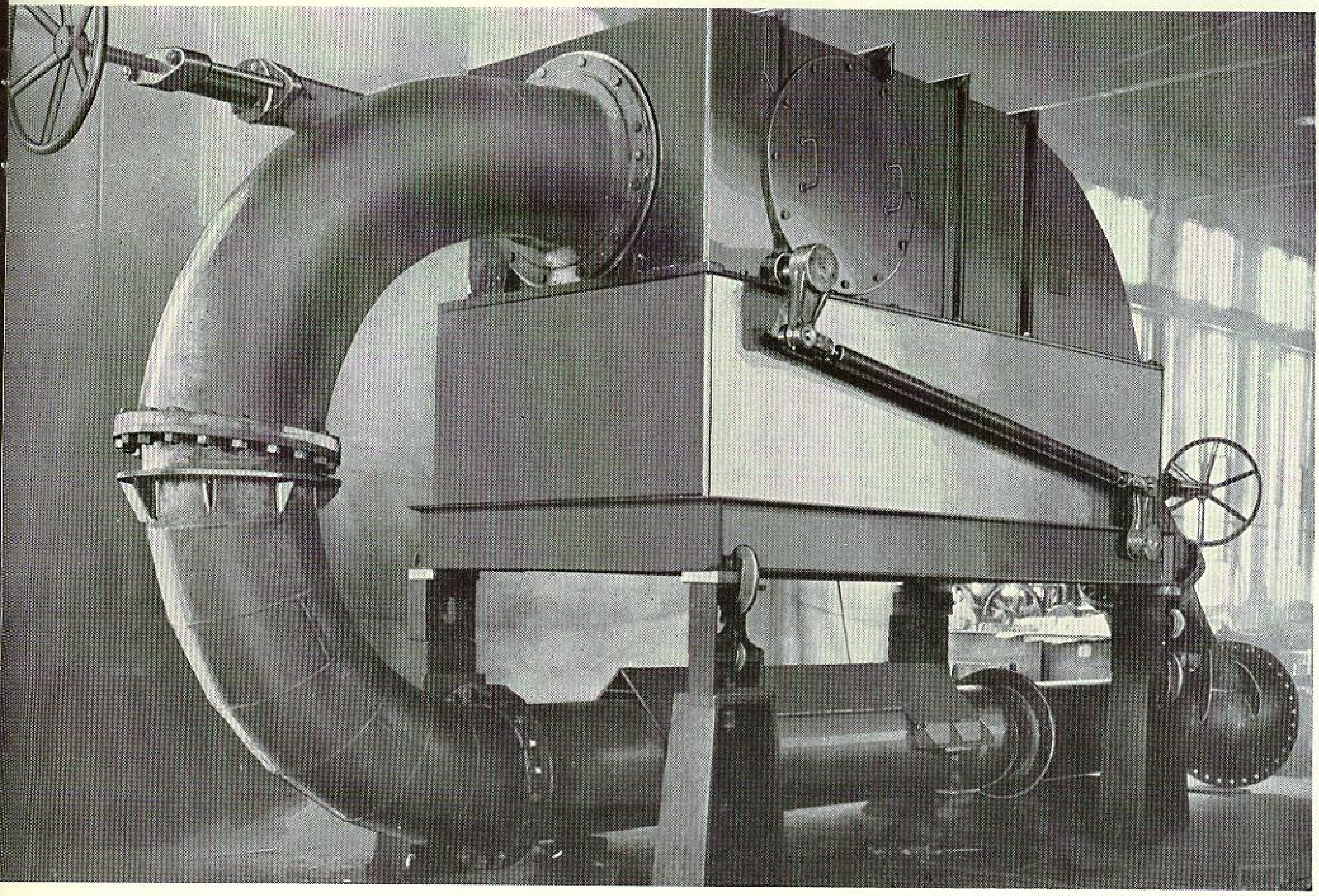


Fig. 13: Side view showing turbine casing with double jet construction and piping arrangement.

Fig. 14: Rear of same unit (*Fig.* 13) completely assembled showing connections for operating the two governor controlled jet deflectors.



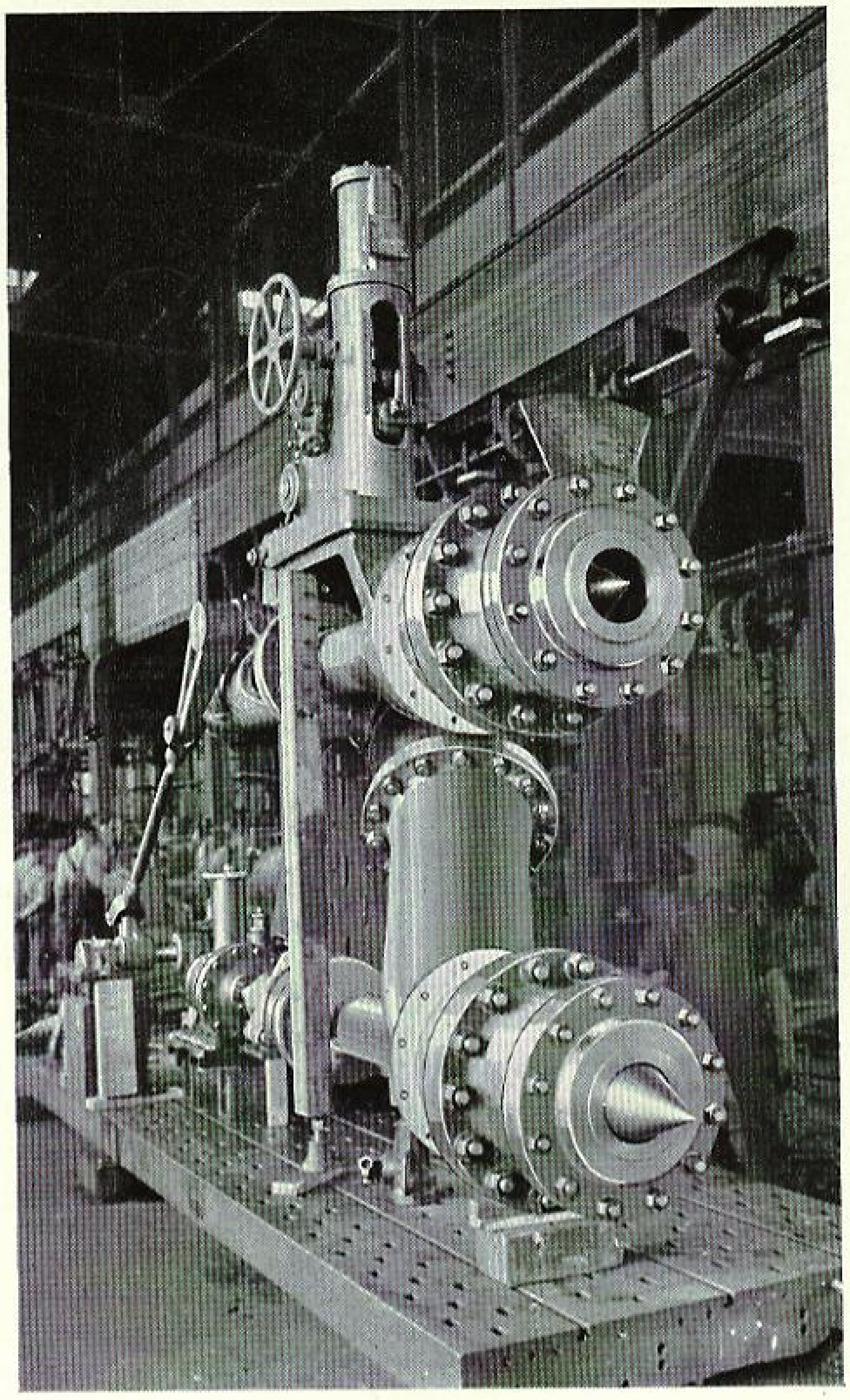


Fig. 15: Governor operated power nozzle and by-pass nozzle.

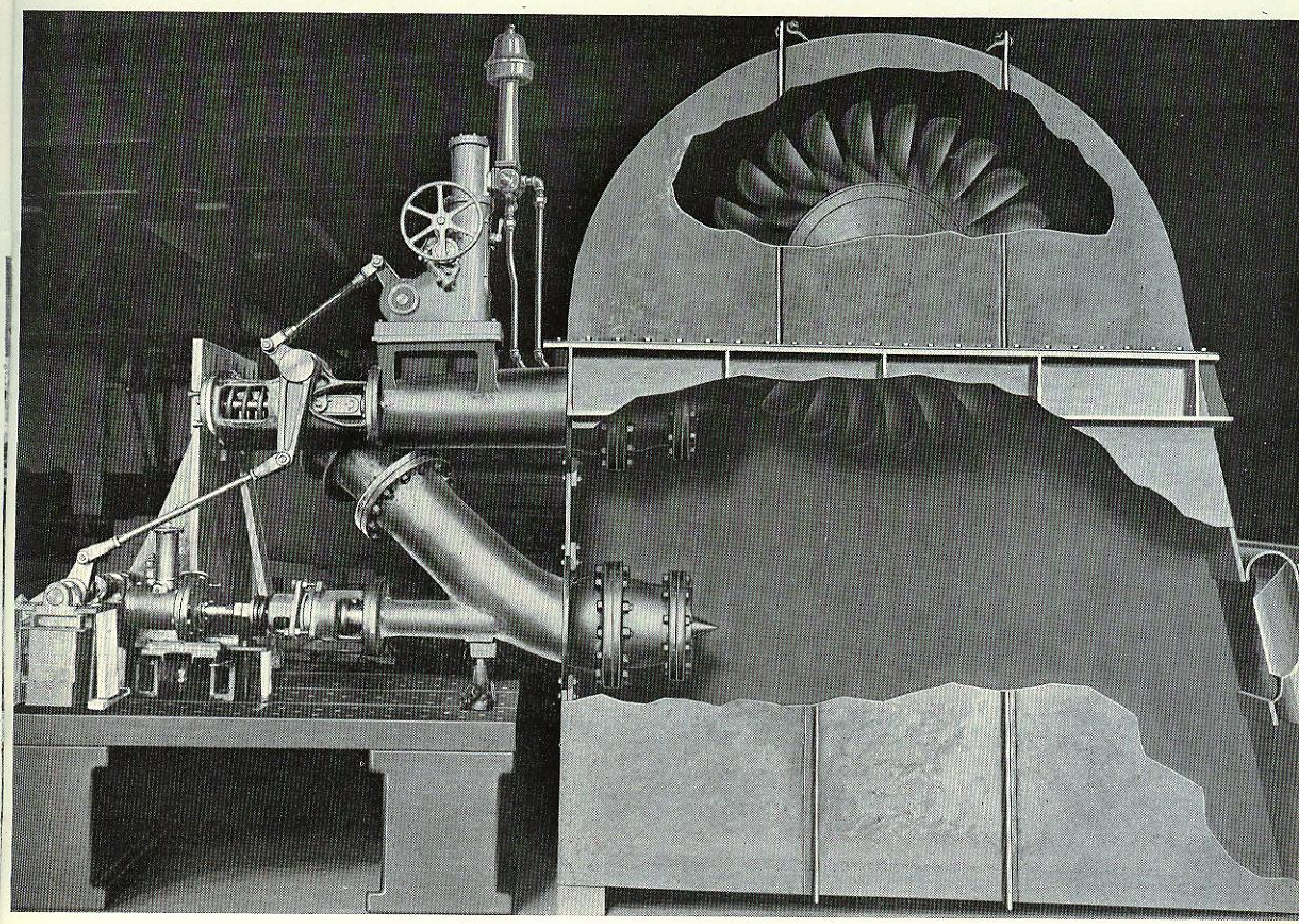
WHERE water cannot be stored but must be passed through the plant, as required for most irrigation jobs in the Western States for example, all the governor regulation is done with a jet deflector, because this arrangement provides utmost simplicity and economy. The operator adjusts the needle nozzle slowly by hand to the amount of water that has to be passed. Synchronous by-pass valves, installed in combination with governor-operated power nozzle regulating equipment, will produce the same results.

With relatively short penstock the needle nozzle opening, which controls the size of the jet and hence the power input to the impulse turbine, can be used to regulate the speed of the unit without setting up undue pressure variation or water hammer. The simplest design of hand-operated needle can be used, when the load carried is fairly constant, such as a centrifugal pump driven by the turbine. But where the turbine drives an electric generator it is necessary to install a governor to directly control the power nozzle opening. Generally the pipe-lines are relatively long in proportion to the head and the control of pressure surges becomes a major problem. It is not practical, as a rule, to install a surge tank close to the turbine because of the great height required. Therefore, when the turbine is equipped with a governor-operated power nozzle, suitable mechanism must be installed to gradually reduce the velocity of the water in the penstock to prevent ruinous water hammer when the needle closes the power jet opening as the load is thrown off, and less water is required. One of two methods may be adopted: (1) use of a deflector which deflects a portion of the jet away from the buckets—Fig. 14, page 13; or (2) using a by-pass valve or pressure regulator—Fig. 15, shown above. The operating principle in both cases is identical in that the initial closing movement of the power nozzle is slow whereas the opening of either the deflector or by-pass needle is rapid. After the power needle reaches the proper position for carrying the load, the deflector or by-pass valve closes slowly and shuts off the water flow.

The operating speed of the power and by-pass nozzles can be adjusted independently so as to assure the proper speed regulation for the unit that is essential to best performance, with a closely-limited pressure rise in the penstock. This method of control constitutes the best speed regulation possible with the added advantages of dependability and the reducing of water wastage to an absolute minimum.

The pictures on these pages show a recent installation of a Smith turbine with governor-controlled power nozzle and by-pass nozzle. The speed of the wheel is held constant automatically as the power demands vary, the water being discharged through the by-pass nozzle to the energy absorber seen at the extreme right, from which it is discharged downstream. The by-pass nozzle in this instance acts as a relief valve to avoid serious pressure rises, as it is set for very gradual closing. These views, illustrating one of Smith's methods, show the type of regulating mechanism installed for Toro Negro Plant No. 2, further illustrated on the next two pages.

Fig. 16: Shop assembly view of a complete single jet Smith Impulse Turbine with by-pass and energy destroyer.



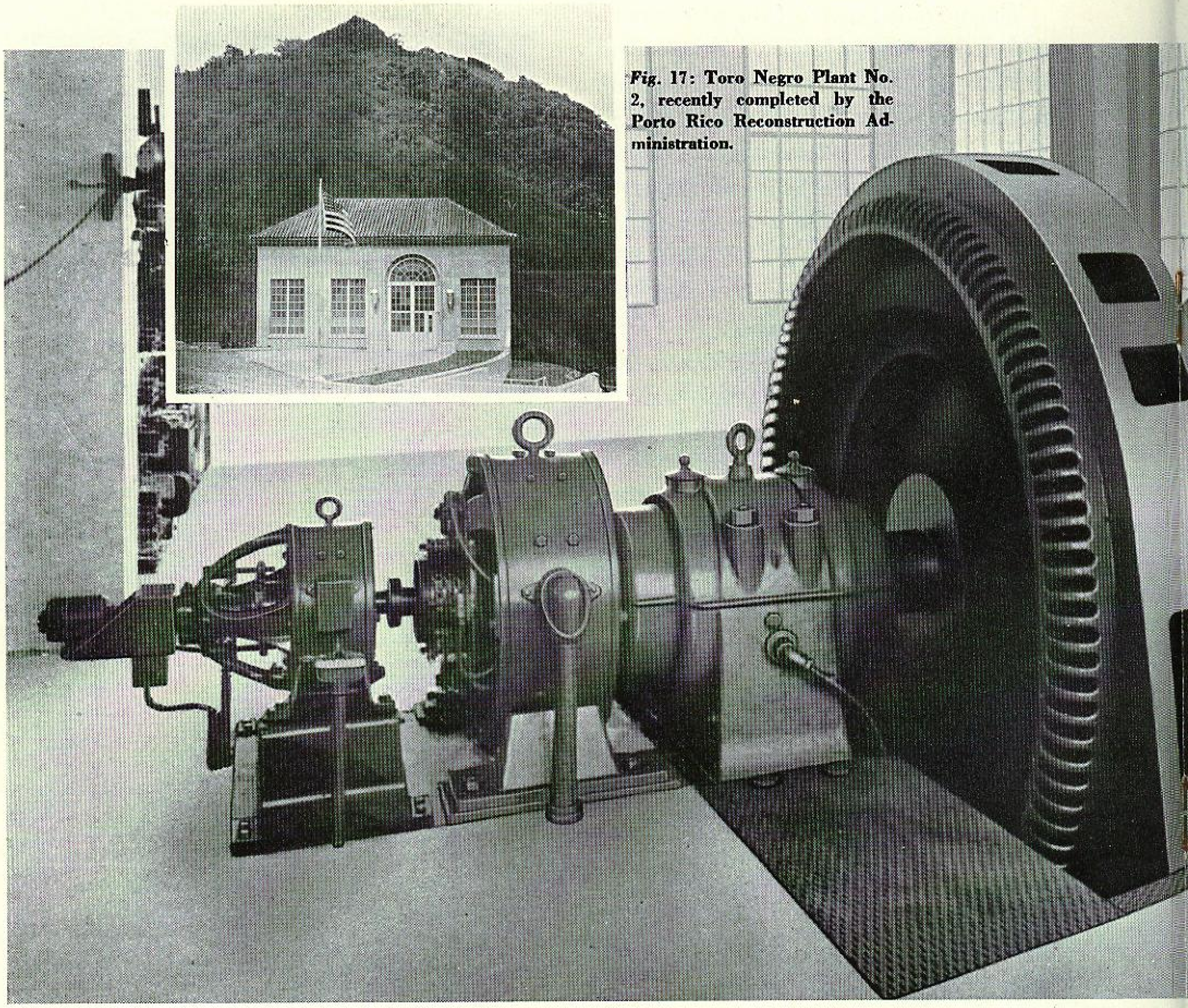


Fig. 17: Toro Negro Plant No. 2, recently completed by the Porto Rico Reconstruction Administration.

Fig. 19: Smith single runner, single jet impulse turbine with by-pass no

For Today's High Hea

MEETING every demand for Impulse Turbines, u extremely wide assortment of standard and spec the unit, regulating mechanism and accessories

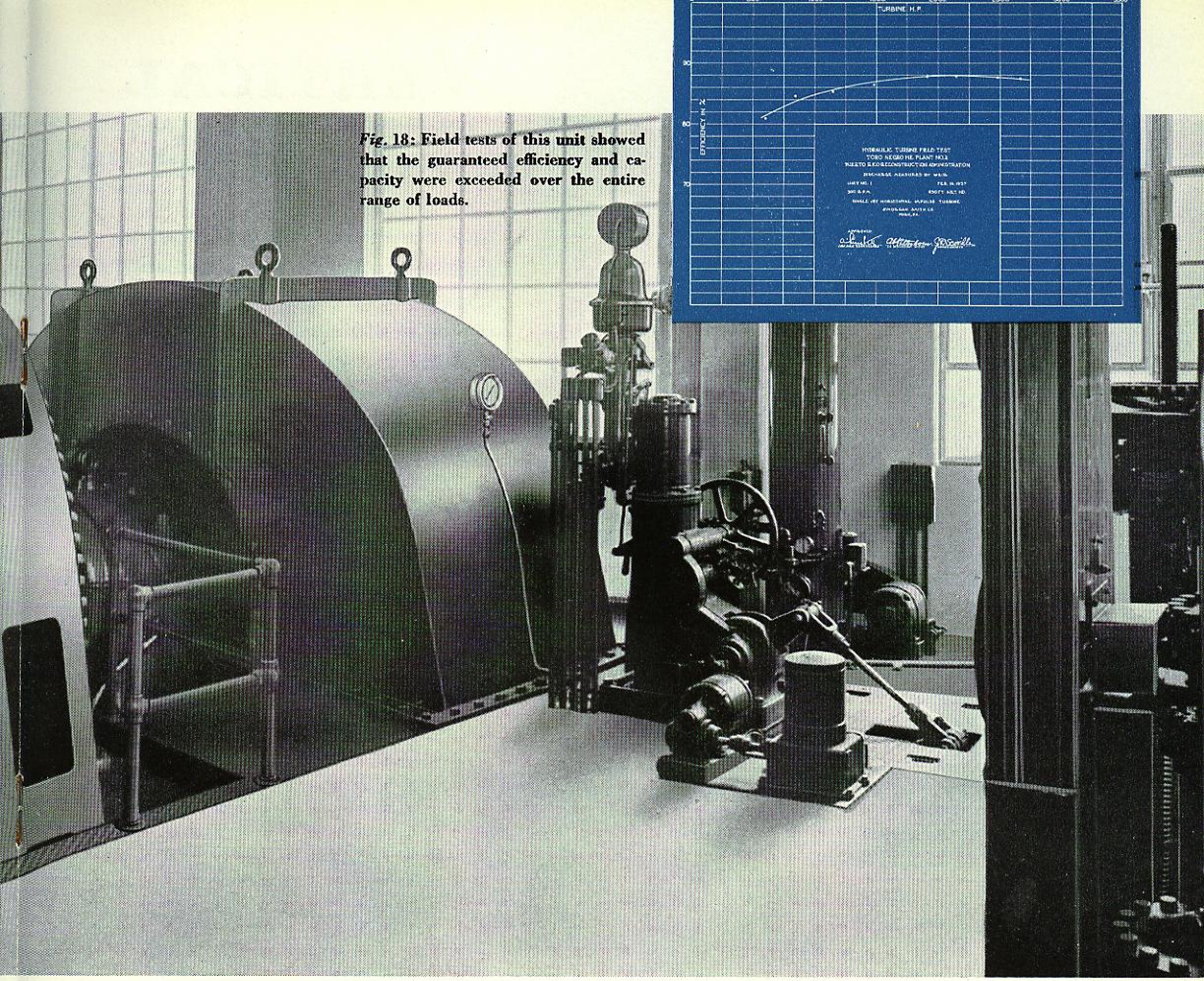


Fig. **18: Field tests of this unit showed that the guaranteed efficiency and capacity were exceeded over the entire range of loads.**

nozzle developing 2700 H. P. at 300 R. P. M. under 630 feet head.

d Water Power Plants

under every condition of service, Smith offers an cial designs, thus assuring the individual user of best-suited to his own individual requirements.

VERTICAL Impulse Turbines

THE Smith Vertical Shaft Impulse Turbine installation at the Pinnacles, Virginia, hydro electric development of the City of Danville, is extremely interesting because of the substantial savings in cost of equipment and power house made possible by the adoption of this type of setting.

Located at the headwaters of the Dan River, the development consists of a power house, diversion dam and storage reservoir. The Big Bend dam, seven miles upstream from the power house, forms a 350,000,000 cubic feet capacity storage reservoir from which the regulated stream flows downstream five miles to the diversion dam, where the water enters the 10,300 feet long

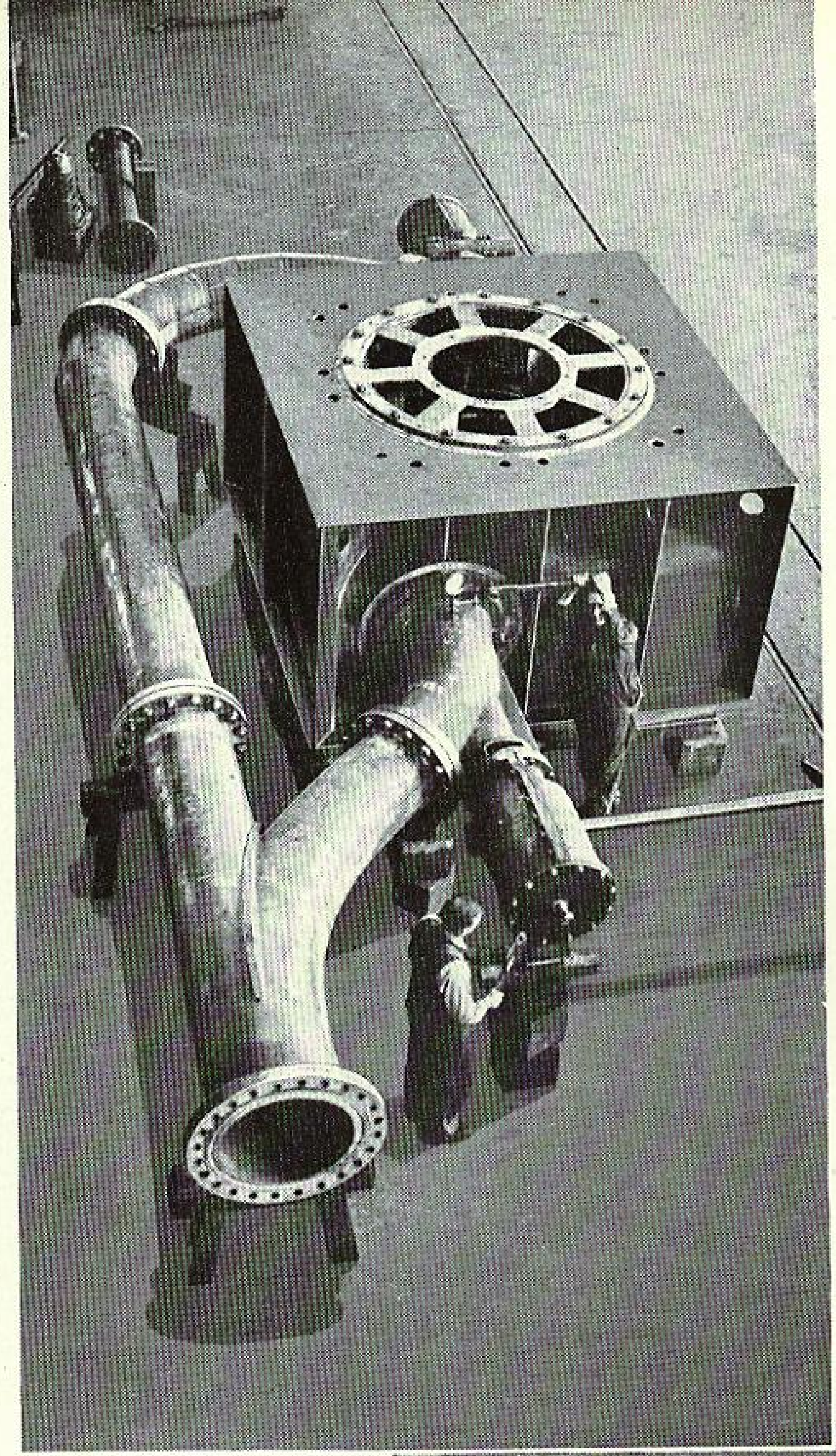


Fig. 20: Smith Vertical Impulse Turbine, single runner, equipped with two jets governor-controlled, arranged to permit holding one jet inoperative thus improving efficiency at all points below 40% of turbine rating.

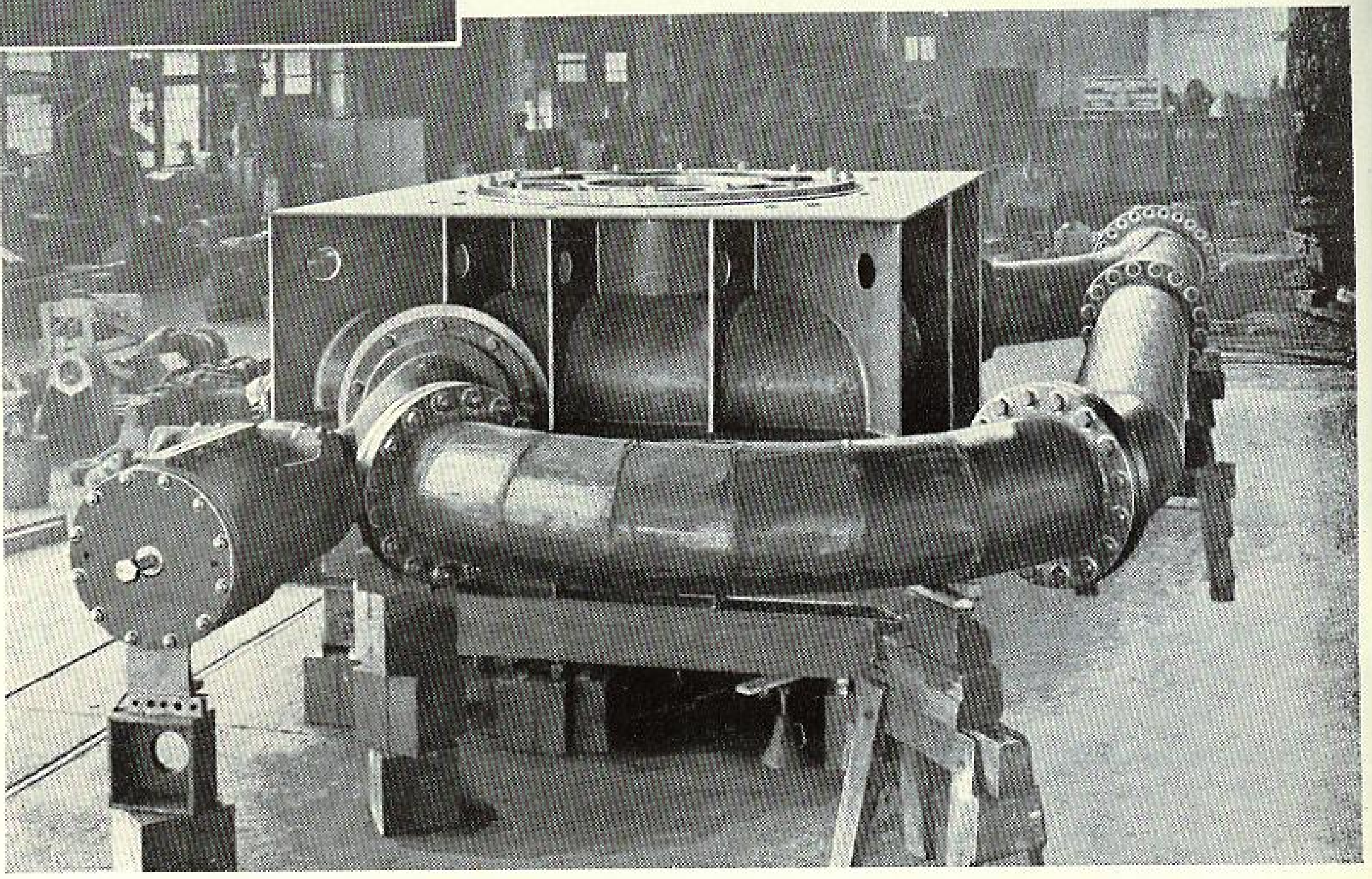


Fig. 21: View of above unit from the downstream side showing all-welded construction of wheel housing and of pipe lines.

pipeline to the power house. A differential surge tank located about 1200 feet upstream minimizes positive and negative water hammer in the penstock.

At the downstream end the penstock divides through a three-way branch into separate lines supplying the three vertical shaft double jet Smith Impulse Turbines, each developing 5000 H. P., at 450 R. P. M. under a net effective head of 660 feet.

An electrically operated Dow "Disc-Arm" Pivot Valve is installed at the intake of the supply line; a butterfly valve electrically controlled is placed immediately downstream from the surge tank; and each leg of the three-way branch is connected to an electrically operated Rotovalve — all valves being controlled from the power house.

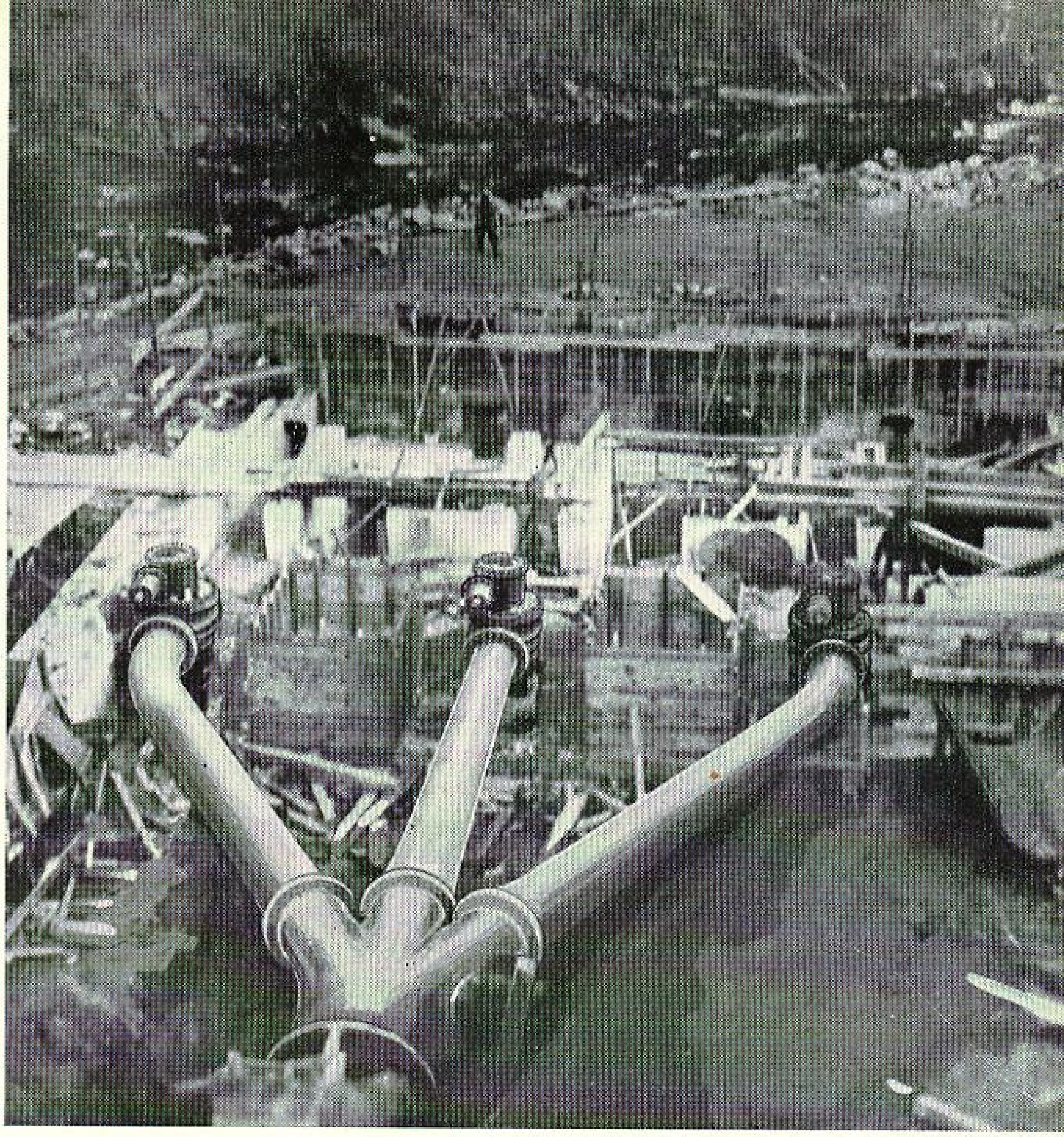


Fig. 22: Field view showing three Smith Vertical Impulse Turbines being installed for the City of Danville, with the three-way branch inlet pipes and Smith Rotovalves in the foreground.

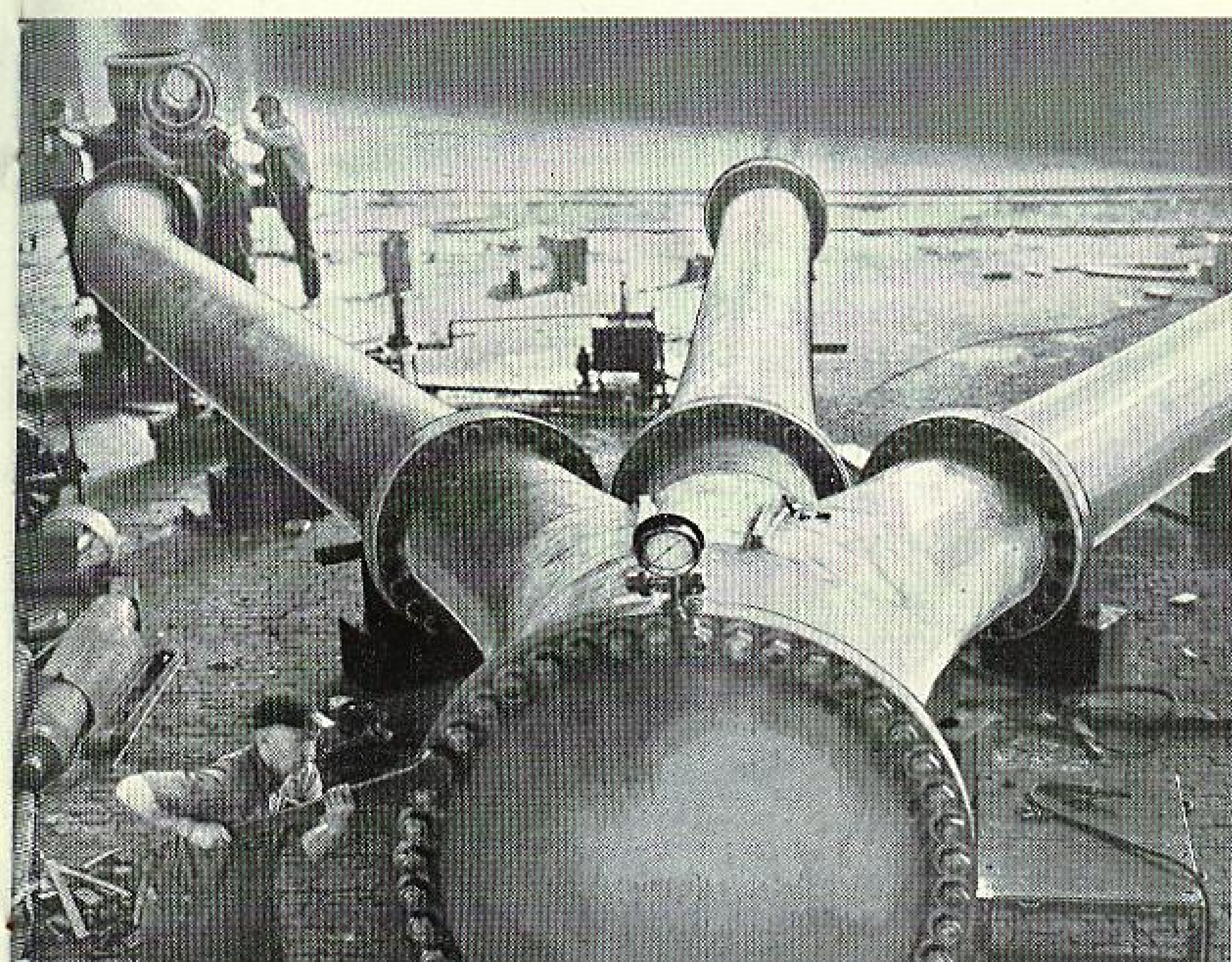


Fig. 23: Close-up of three-way branch showing fabrication by Smith's advanced welding processes.

Fig. 24: Shop pressure test of welded three-way branch and inlet pipes assembled with Rotovalves.

Laboratory

MOST of the recent major advances in the art of designing hydraulic turbines have come about as the direct result of painstaking research and laboratory experiments. Tests conducted in the Smith Hydraulic Laboratory have contributed in no small measure to this recognized progress which has made a substantial contribution in the form of better and more efficient turbines and *in reduced costs to users of water power.*

The Smith Laboratory is completely equipped with the most modern apparatus known for accurately testing water power machinery of every type and the almost countless tests, over a long period of years, have determined the correct and most ef-

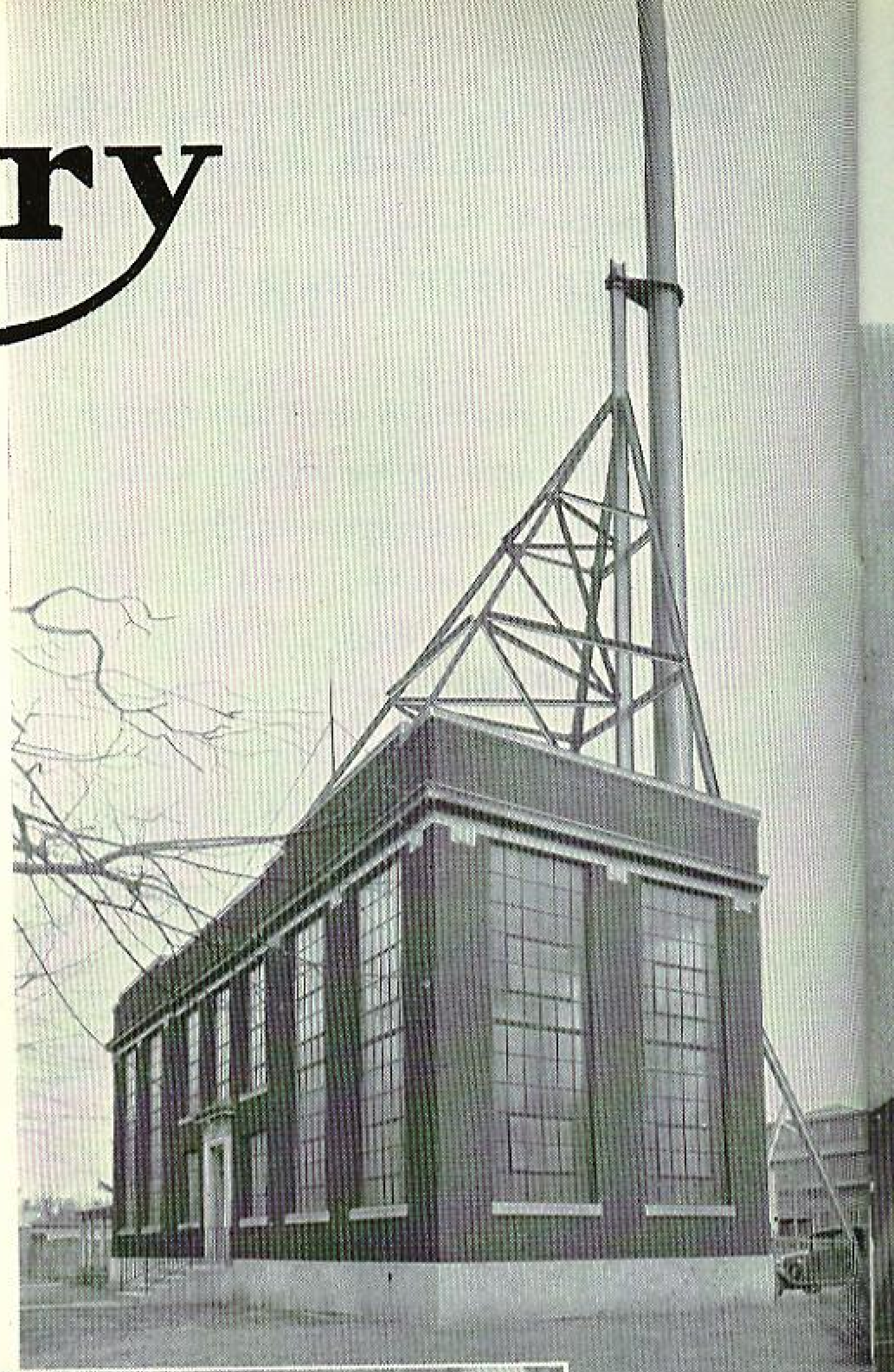


Fig. 25: The Smith Hydraulic Laboratory.

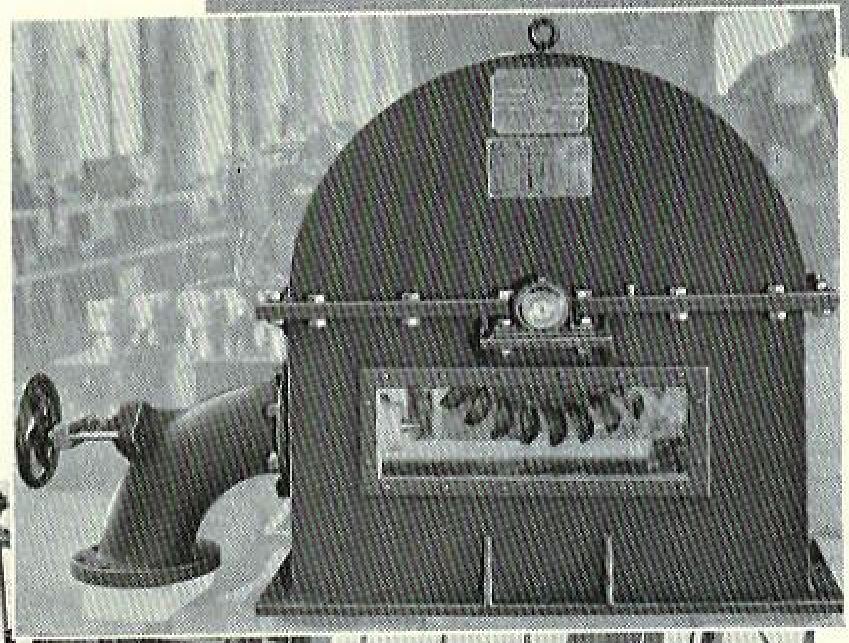
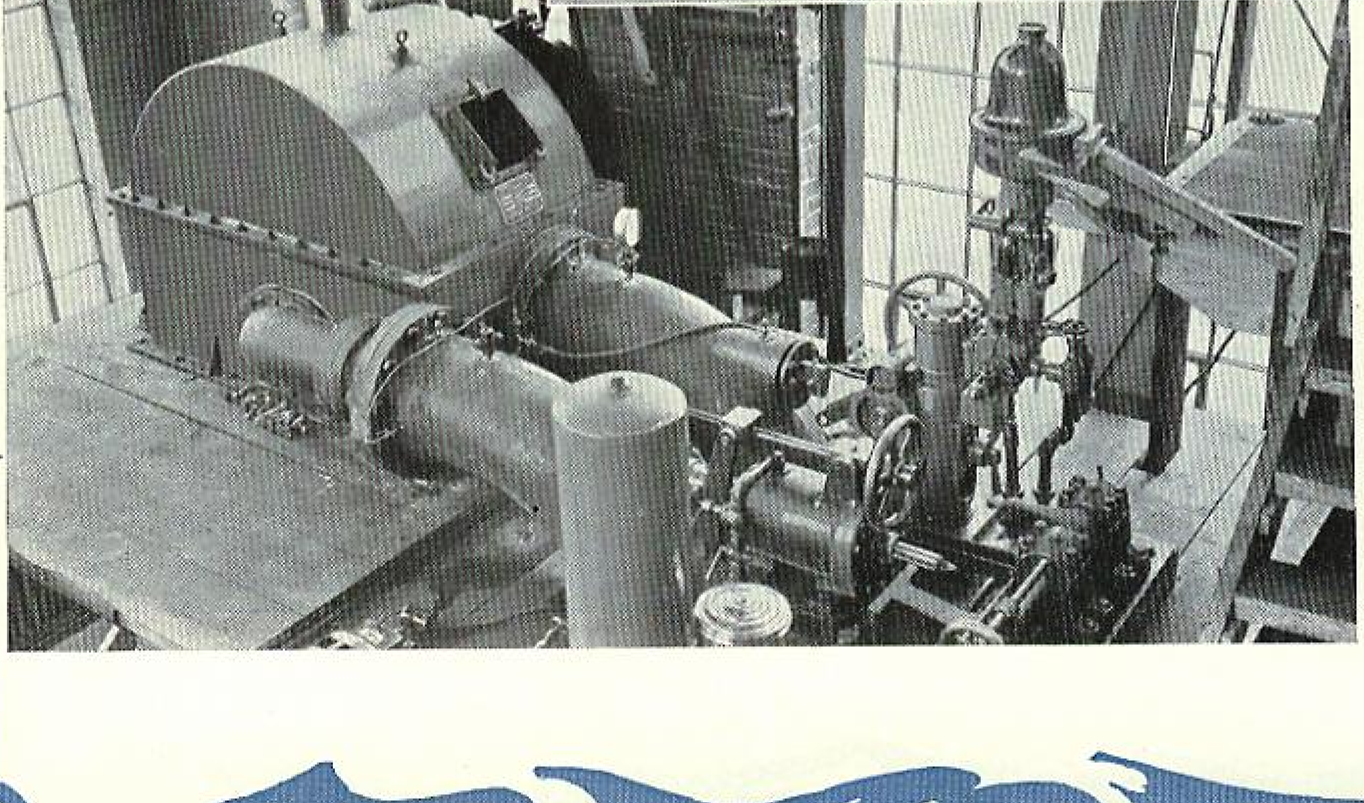


Fig. 26: Small turbine for laboratory use, with glass windows permitting observation of action of water jet upon the runner buckets.

Fig. 27: An actual test being run in laboratory.



ficient design to meet every turbine service demand. These tests include all parts of the turbine and adjacent water passages.

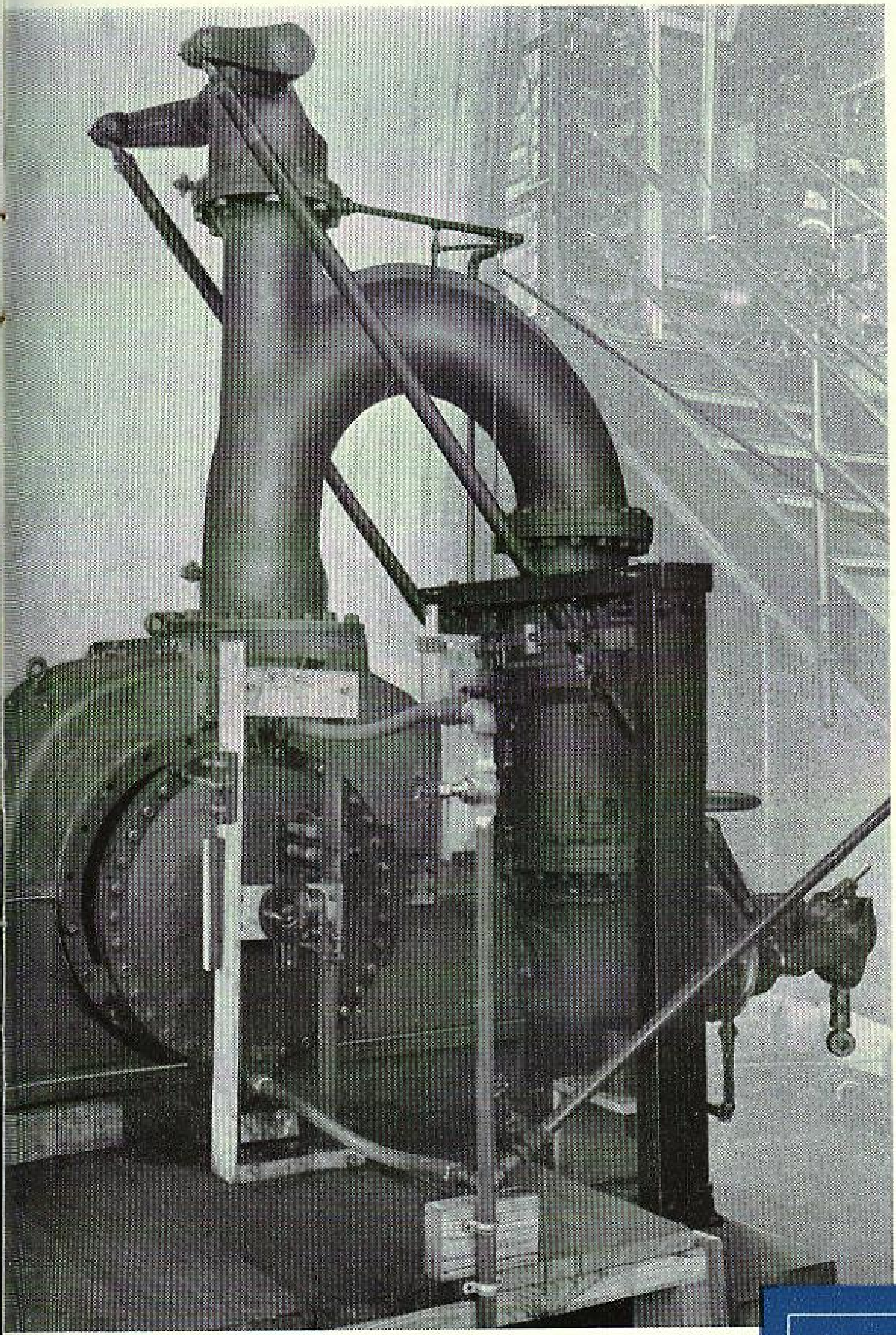


Fig. 28: Laboratory test of a double jet impulse turbine before shipment for installation in a Foreign Country.

The results have been carefully recorded and classified so every customer today receives the benefit of the sum-total of all of our laboratory and field experience, in his own installation.

Impulse turbine tests have been all-inclusive: design of runner buckets for shape and angle and spacing on the runner; nozzle shapes for all types of service; and the proper location of deflectors and baffles in the turbine housing. All of these factors and others have an important bearing on the efficiency and resistance to erosion and cavitation of an impulse turbine, and the proper selection of the correct combination of each must be made in designing the unit to fit existing conditions of each contemplated installation.

Consequently, Smith Impulse Turbines meet the most exacting requirements—turbines that will reach an efficiency of 89% under favorable conditions; run at specific speeds up to ten with successful results and provide a marked reduction in cost of generating equipment.

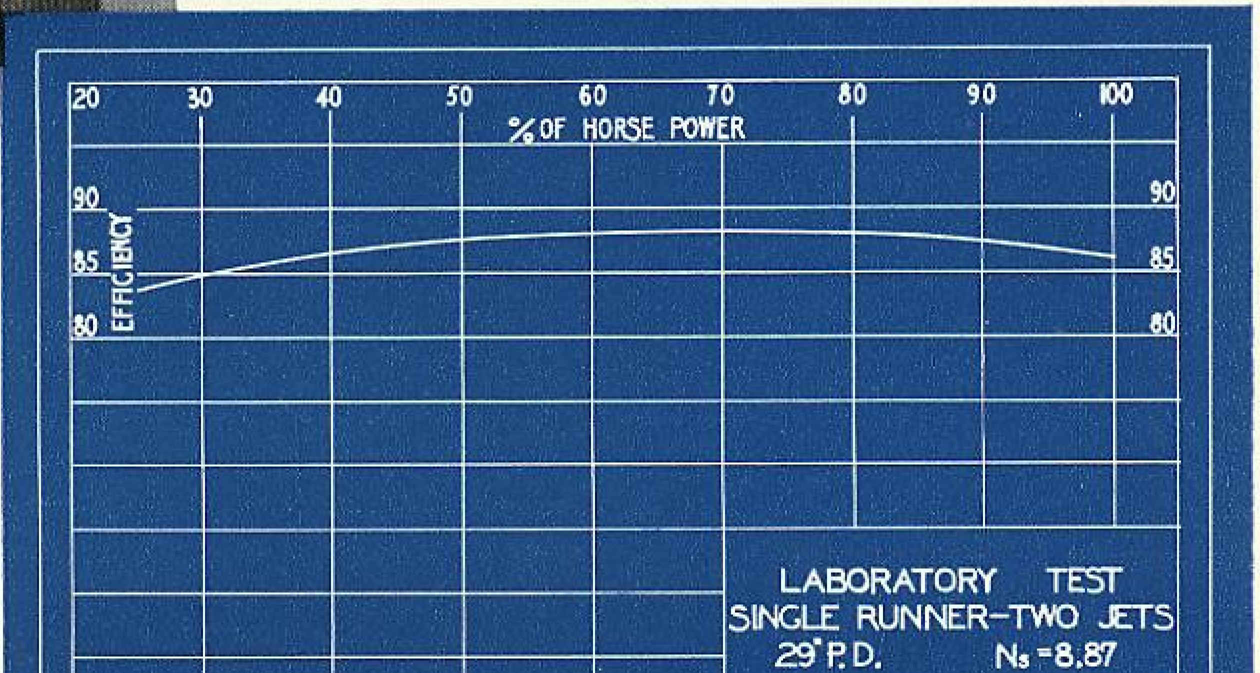


Fig. 29: Chart showing results of test of unit shown above.

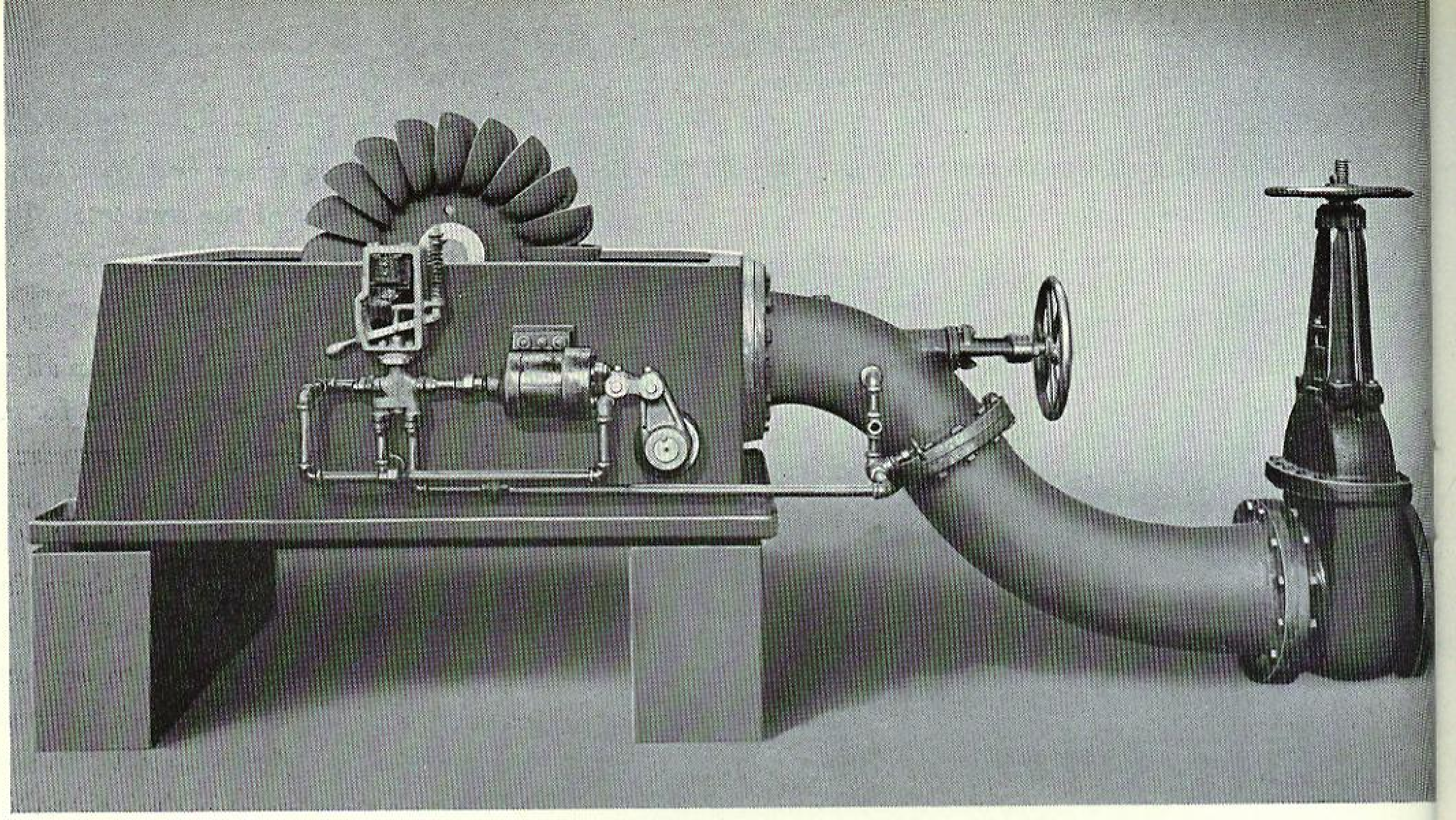


Fig. 30: Unit equipped with solenoid operated jet deflector for emergency shut-down to be installed in semi-automatic plant where power produced is absorbed in a large system and no speed regulation is required.

Typical Arrangements

IT IS nearly impossible to show all types of Smith Impulse Turbines for the reason that the requirements of each installation vary to a great degree.

Six typical plan views are shown, however, on pages 23, 24 and 25, in order to illustrate different basic types of installations. But we are prepared to furnish any design and size of impulse turbine from the smallest and simplest, hand-controlled unit to the largest, multiple-jet, automatic, dual-controlled turbine, in either horizontal or vertical settings.

It is obvious that the problem involved in a contemplated impulse turbine installation is of such proportions that it is impossible to present an intelligent description until the basic factors have been determined.

Our Engineering Department will be of great assistance in the selection of the turbine design best-suited to your own particular needs. It will simplify matters, and enable the Department to serve you more quickly, if you will send in the amount of head, quantity of water available and designate the typical setting which, in your opinion, appears to be most desirable. If you can accompany your inquiry with a rough sketch or drawing of existing conditions it will be of help to us in interpreting your problem.

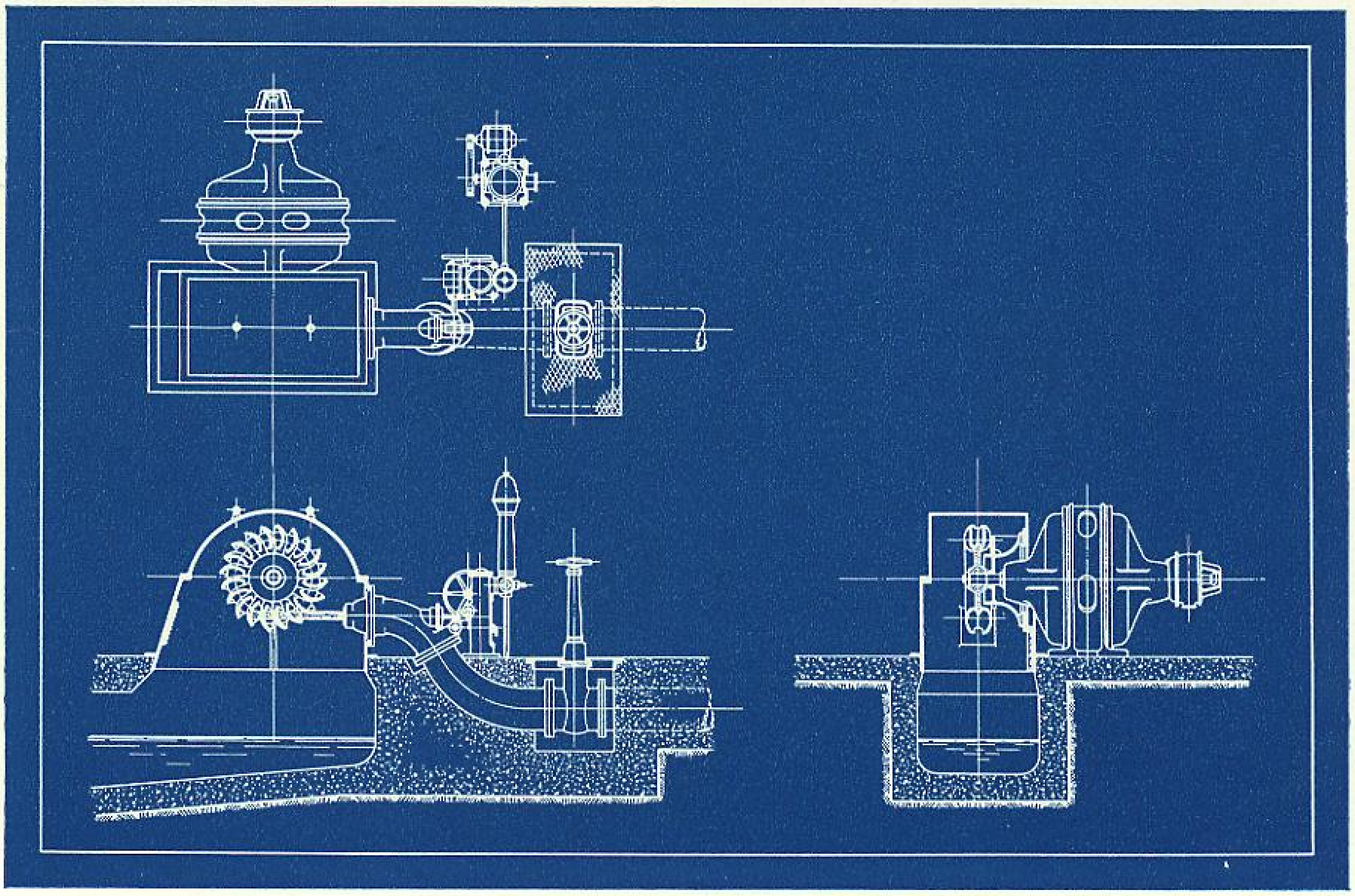


Fig. 31: An economical installation suitable for small and medium capacities, where the penstock is relatively short, which permits the use of a governor-operated needle, thus saving water and providing fair regulation.

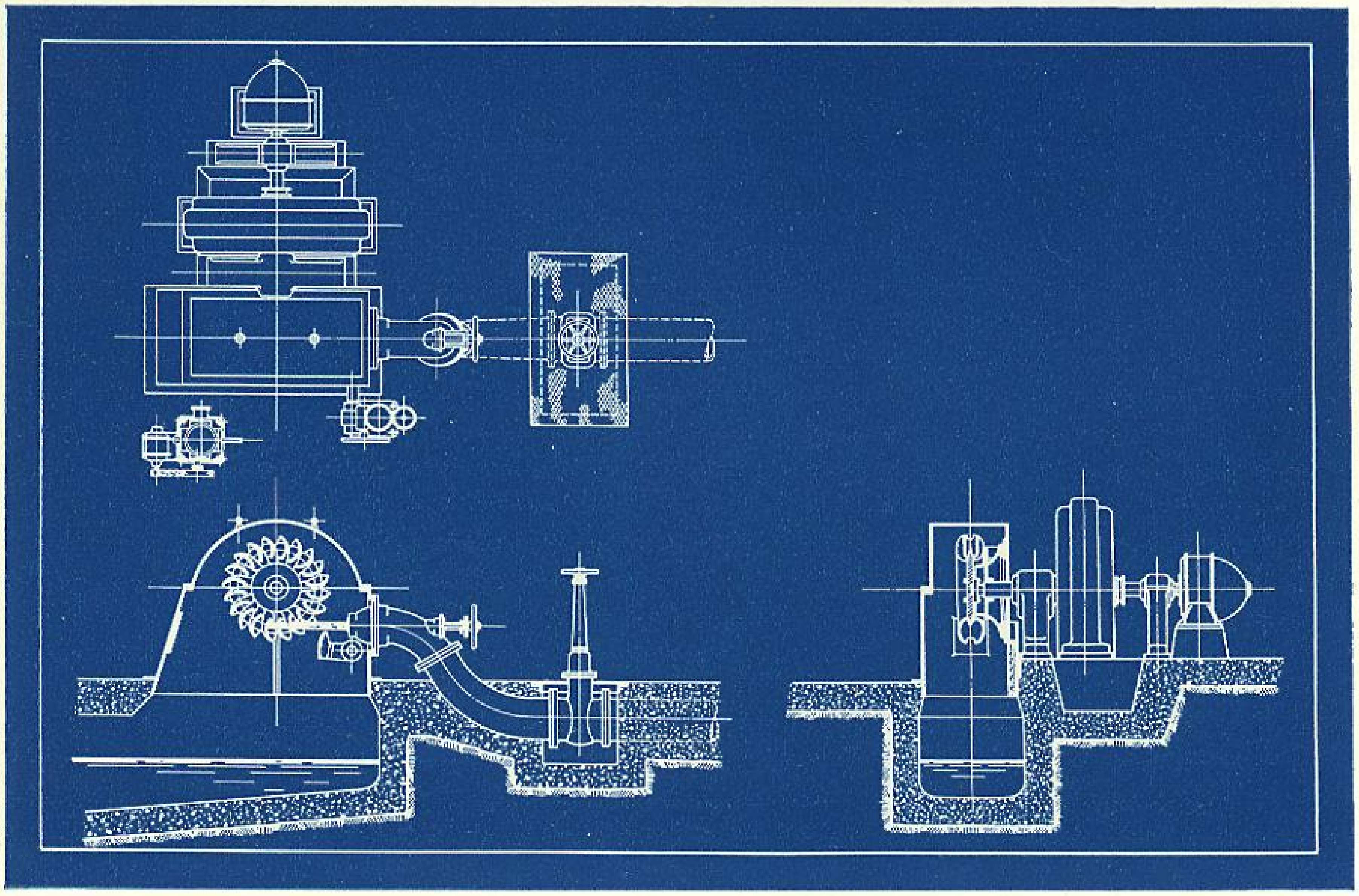


Fig. 32: For medium and large capacities where the penstock is relatively long, close regulation desired and water saving unimportant. The jet deflector is governor-controlled and the needle is manually adjusted slowly to avoid excess pressure surges.

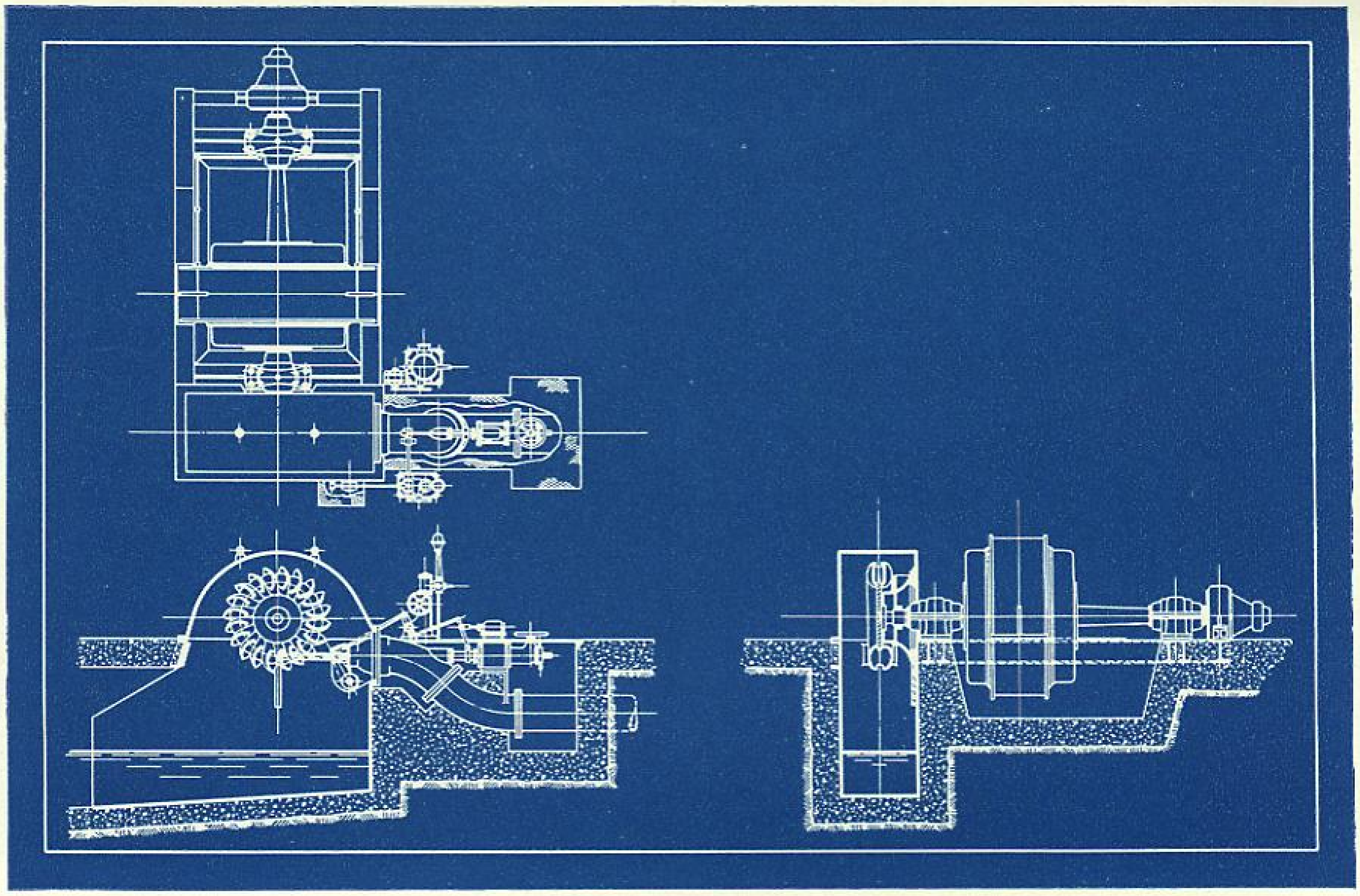


Fig. 33: Dual-control permits the use of a long penstock and gives close regulation without incorporating additional fly-wheel effect. Generator can be of the pedestal bearing shifting type and the tail pit steel lined, if desired.

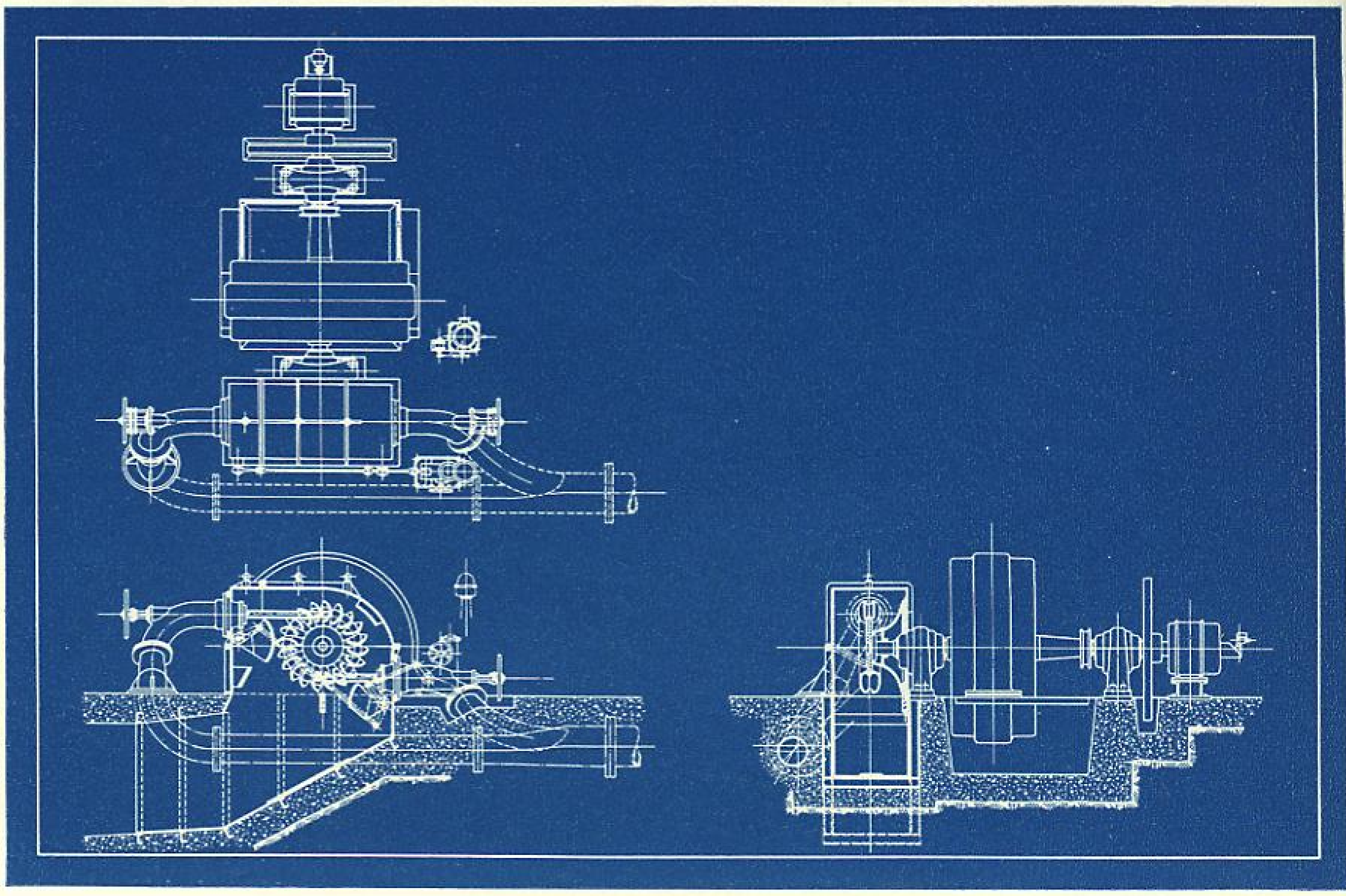


Fig. 34: A single runner double-jet installation for larger capacities, frequently used to increase the speed 41% above that obtained by using a single jet as shown in *Fig.* 32, Pg. 23. A fly-wheel can be installed between the outboard bearing and exciter if very close regulation is required.

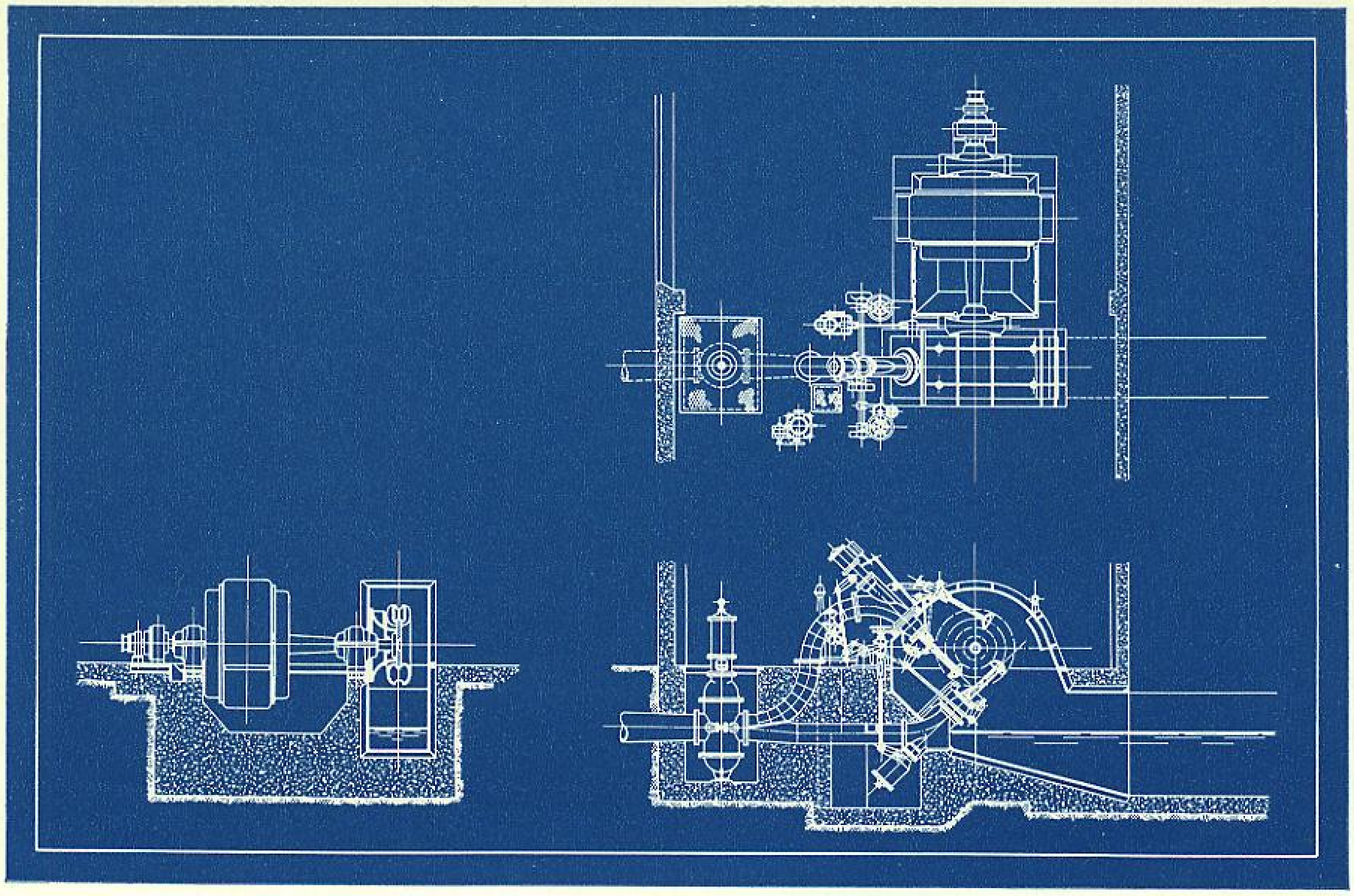


Fig. 35: Type of installation with single runner, double-jet turbine adaptable for large capacities under high heads and relatively long penstocks. Dual-control is used and for light loads one needle can be closed allowing the other to operate at high efficiency.

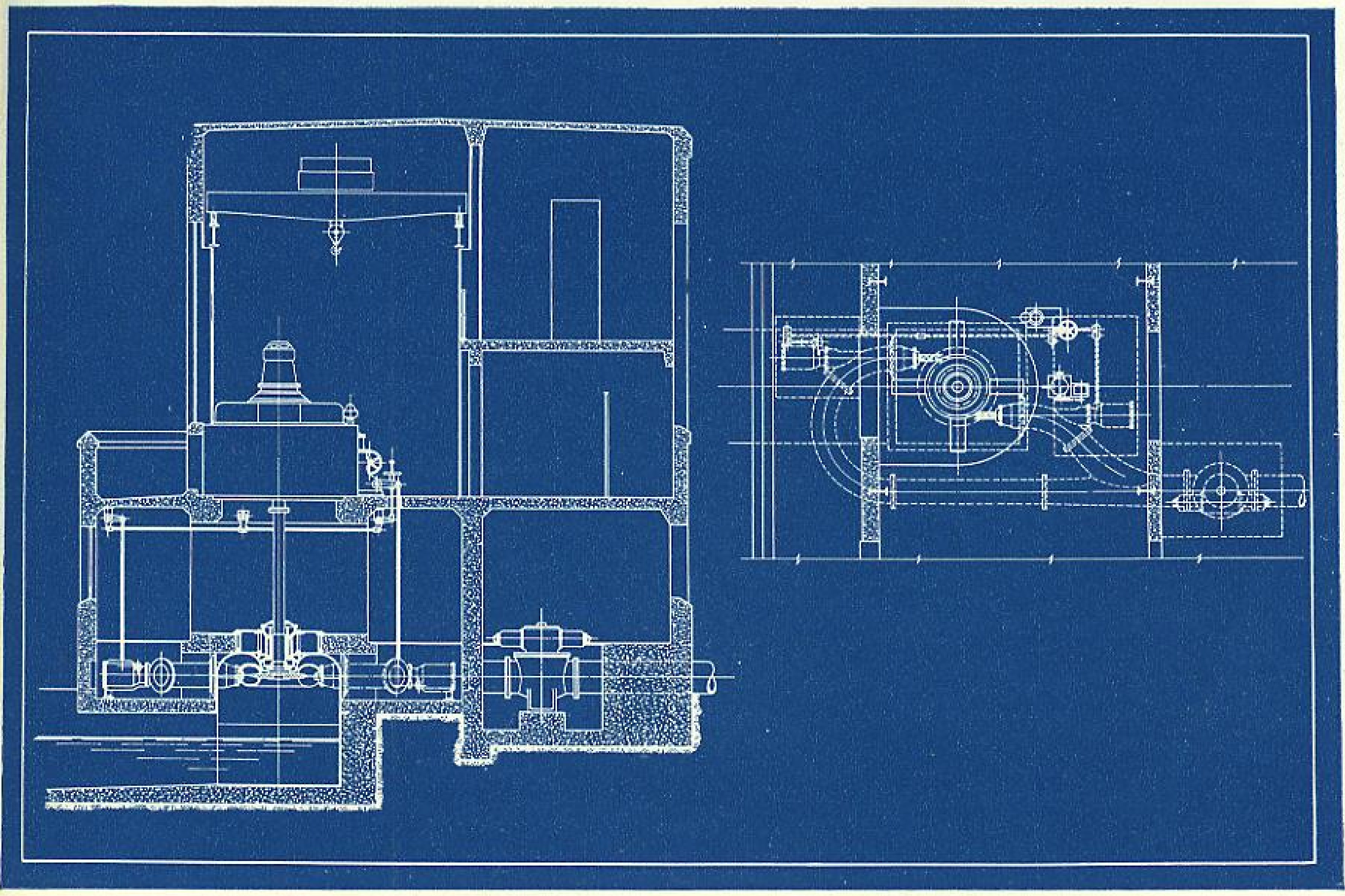


Fig. 36: Typical installation showing a single runner, double-jet vertical impulse turbine. The power nozzles are shown under governor control. For long penstocks the dual-control is suggested in order to obtain quick jet deflector action and slow needle movement. Runner can be set very close to tail water.

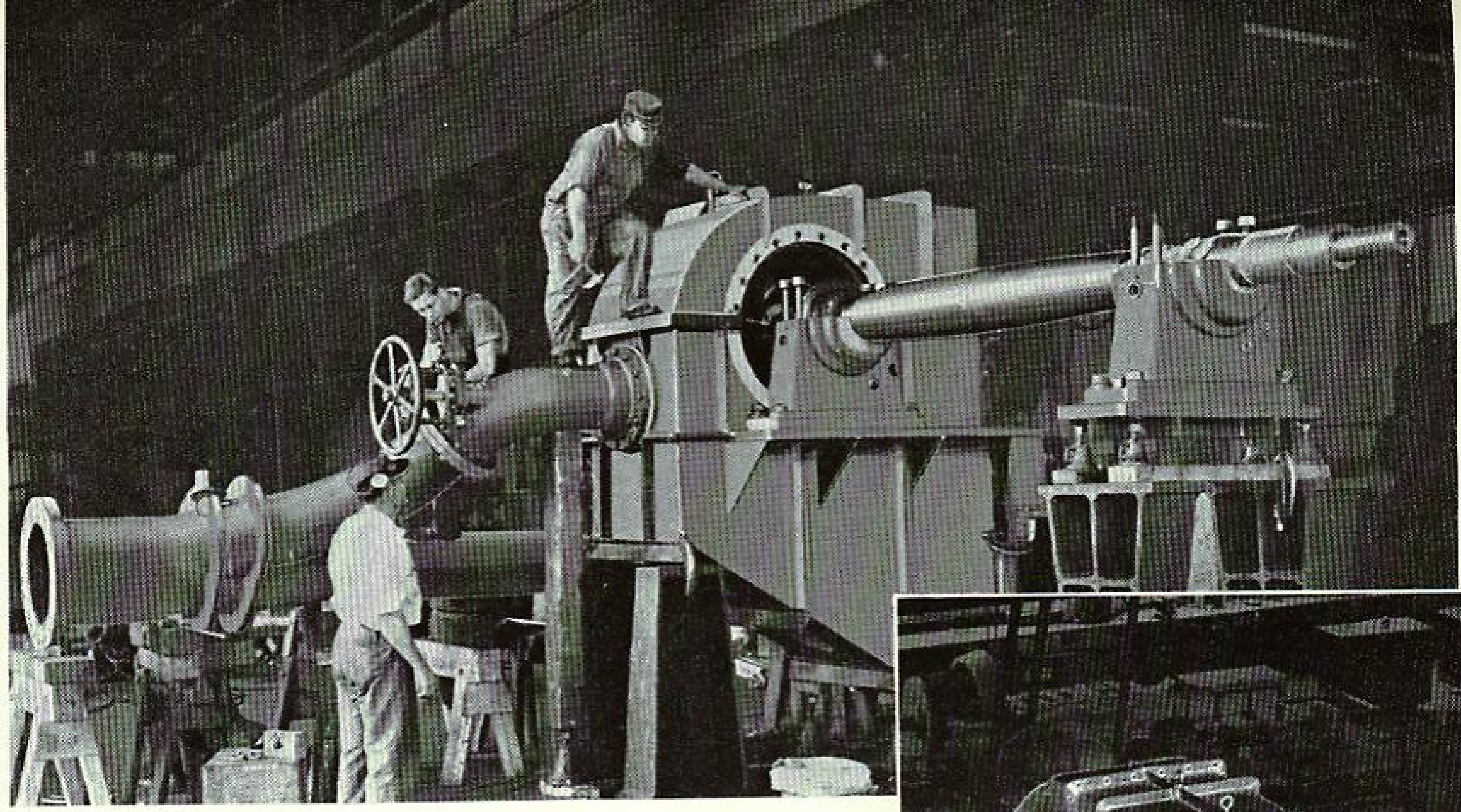


Fig. 37: Workmen completing one of two units for installation in Colombia, S. A., showing generator shaft, bearings and welded steel discharge liner.

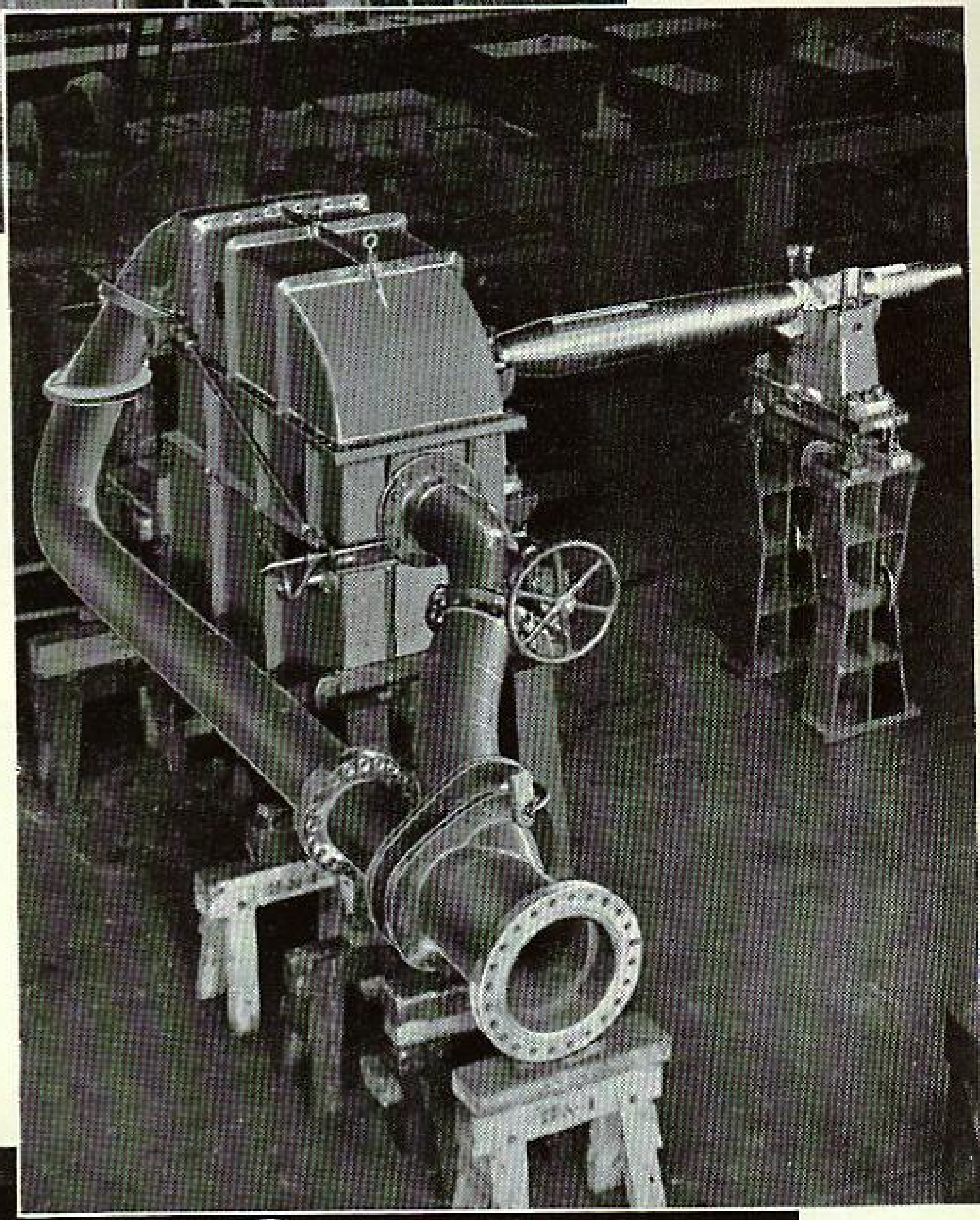


Fig. 38: Factory view of single runner, double-jet turbine to develop 2500 H. P. at 720 R. P. M. under 655 feet net effective head.

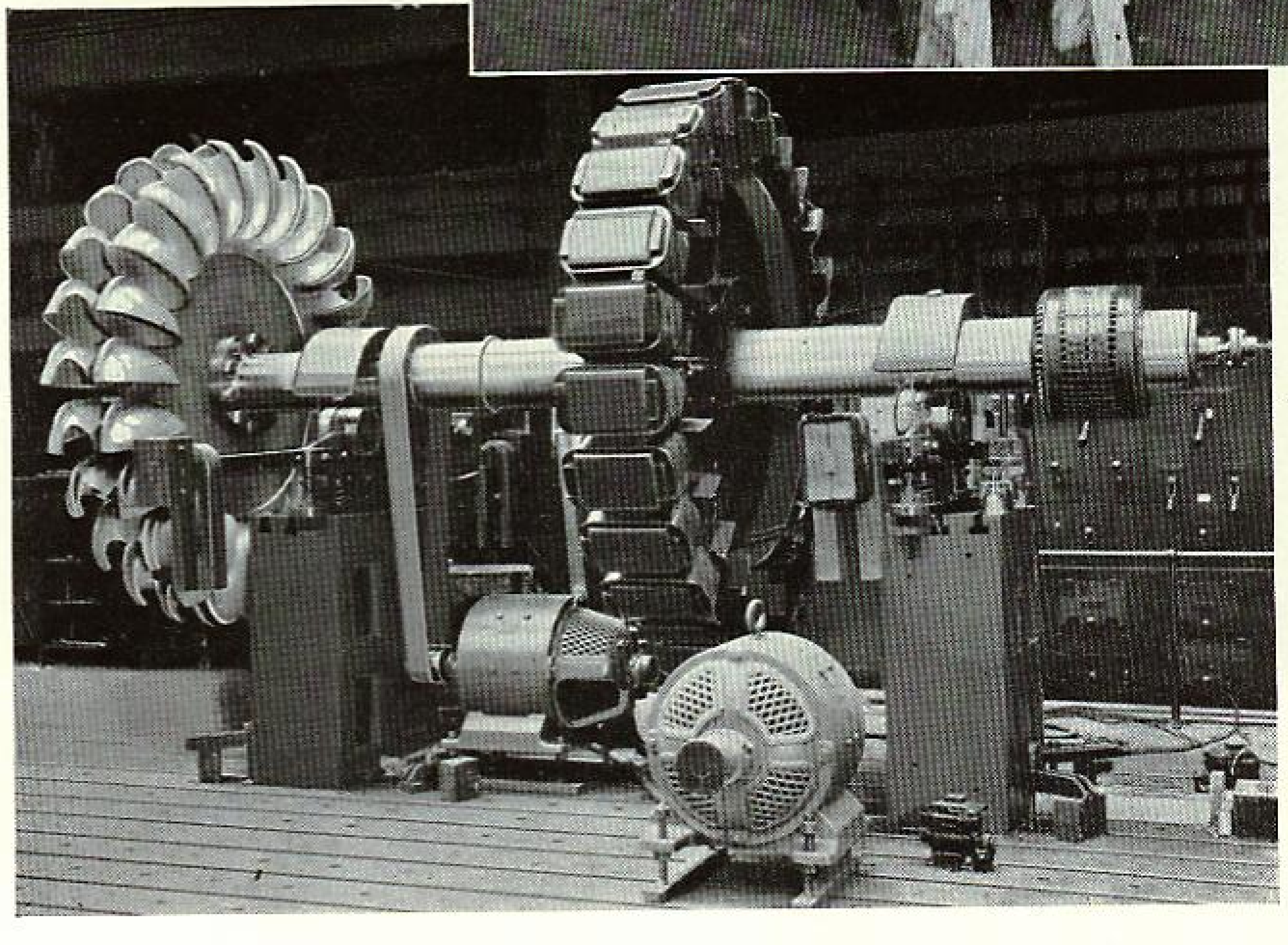


Fig. 39: Dynamic Balance Test of runner and generator rotor.

Valves ✓

REPRESENTATIVE valves, in Smith's complete line, which illustrate a few of the many types we build.

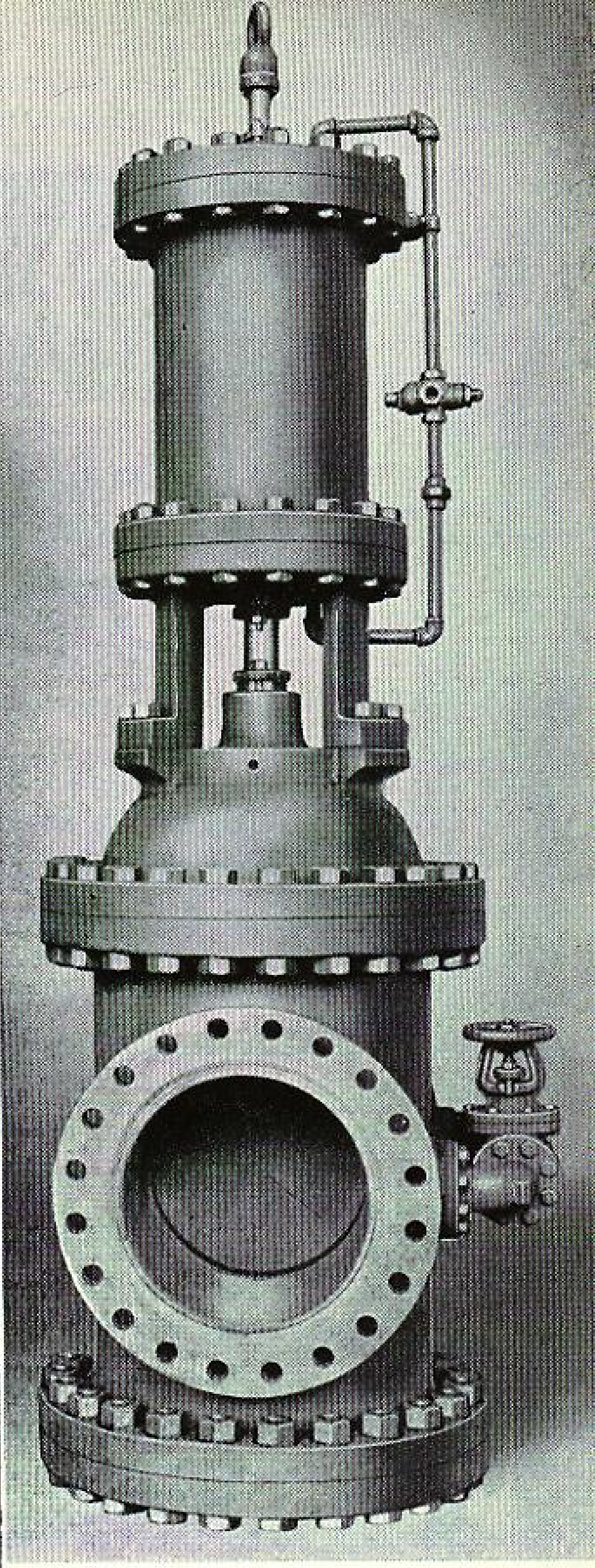


Fig. 40: Follower Ring Gate Valve hydraulically operated.

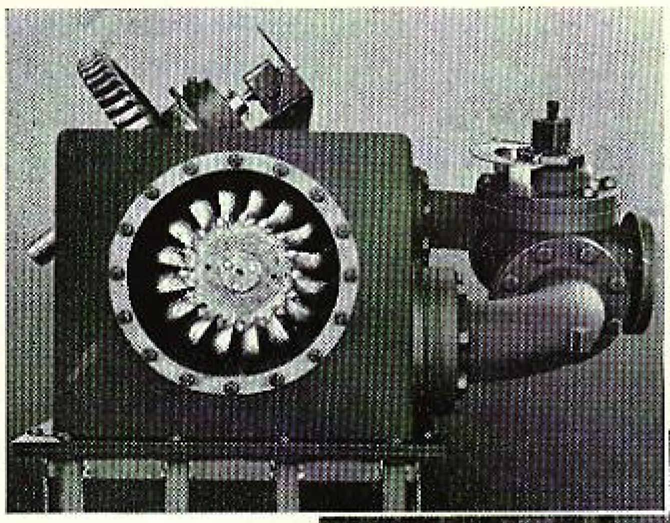


Fig. 41: Two impulse wheels, operating in reversed rotation, used in controlling a gate valve.

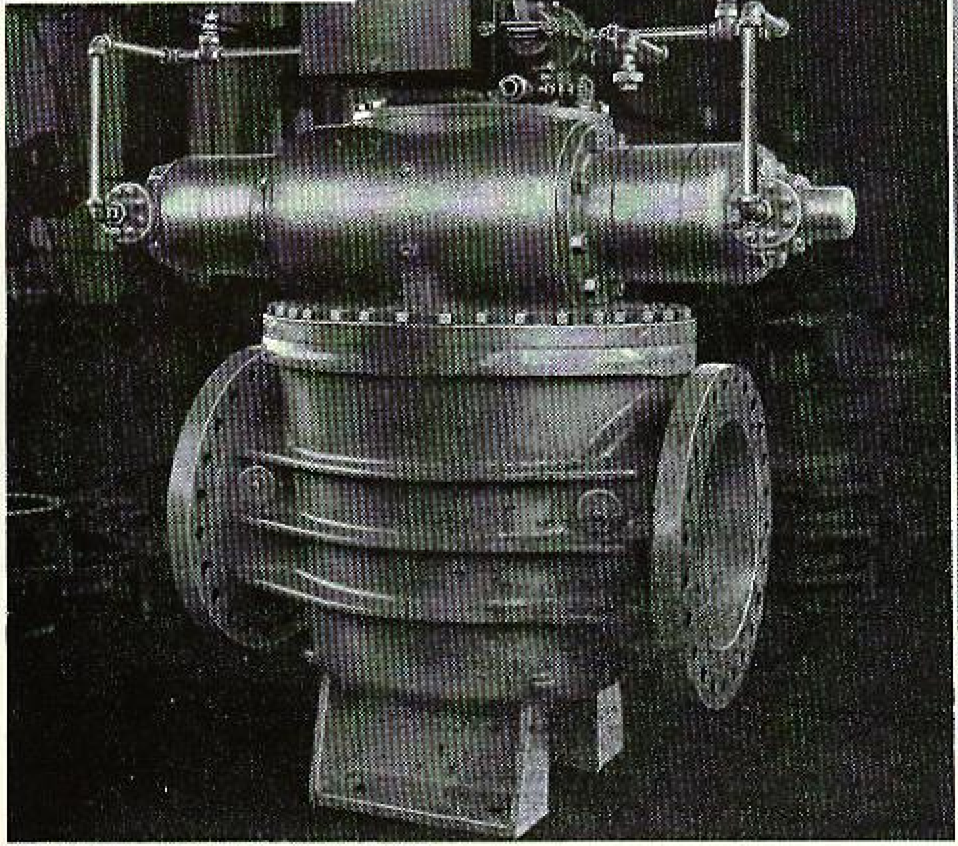


Fig. 42: Shop assembly view of one of the Rotovalves installed for the City of Danville showing the electrical equipment used for control.

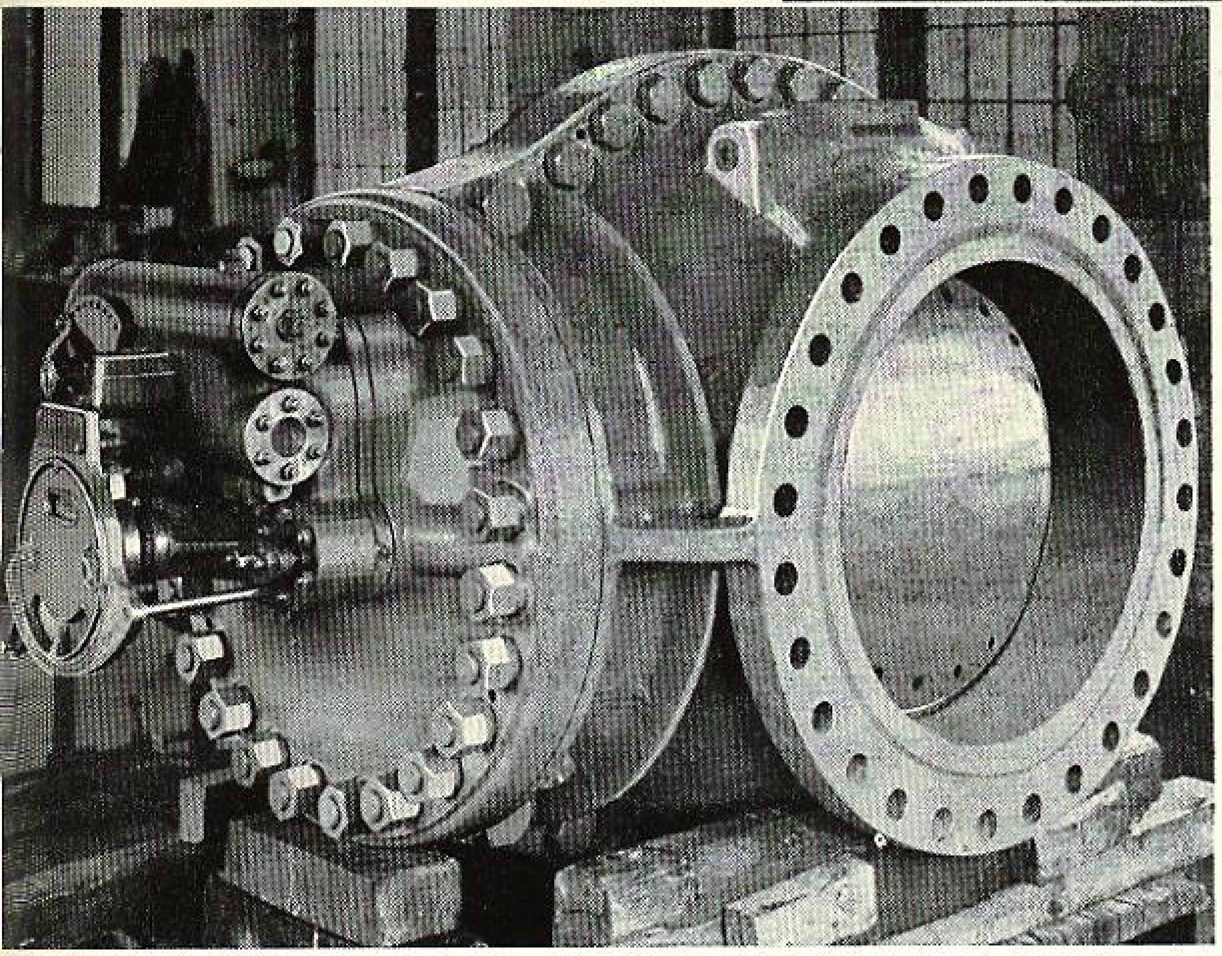


Fig. 43: Special 30″ hydraulically operated Sphere Valve for high head installation.

SMITH'S Line of Valves embraces all types required for water control from the simplest gate valve to the most complicated types of designs and sizes.

Valves for high and low pressure. Also, Dow "Disc-Arm" Valves for turbine intakes, penstocks, regulation of flow from dams and reservoirs. Rotovalves, of which one is shown directly to the left above, are built in standard sizes up to 48″ and in special larger sizes. In addition, there are Butterfly and other valves of special design, including Howell-Bunger for free discharge.

WATER

How to measure it

THE first step in deciding upon the size of the turbine to be used, in a given location, is to determine the height of fall (head), and the amount of water flowing in the stream, in cubic feet per second.

The static head is represented by the vertical distance from the water level in the forebay to the tail water level.

Usually, Impulse Turbine Power Houses are located some distance downstream, from the dam, and the water has to be conducted to the turbine through a penstock. Necessarily this vertical distance is measured by a spirit or engineer's level.

Weir Measurement of Water Quality

THIS method is ideally suited to measuring the flow of small streams, where impulse turbines are to be installed.

A weir is a sharp crested dam situated so that all the water will flow over it unrestricted. It is constructed by placing a board across the stream, at a point which will permit a pond to form above.

A notch is cut in the board, with both edges and bottom beveled sharply on the downstream side, as is shown in Fig. 44. The bottom of this notch is called the crest, and it should be *perfectly level with vertical sides.*

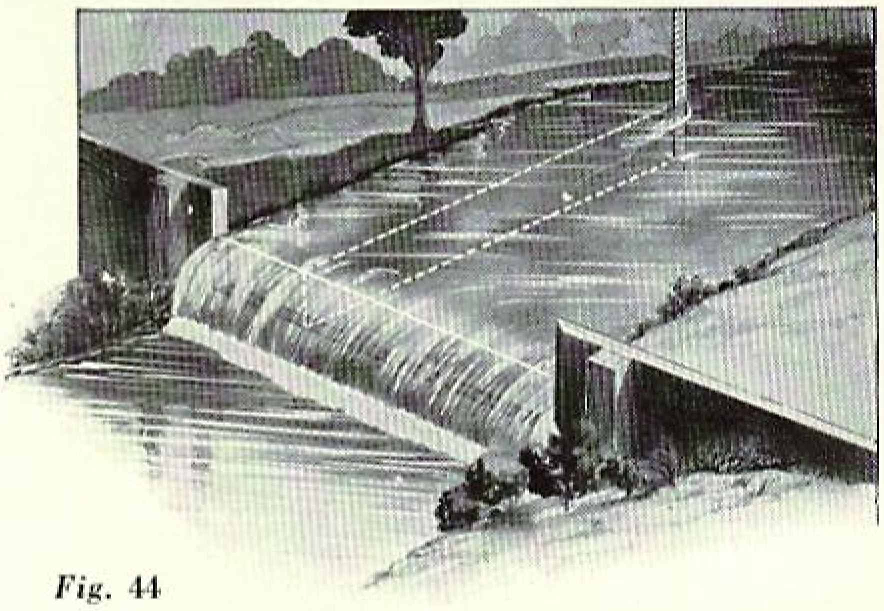


Fig. 44

In the pond back of the weir, at a distance not less than the length of the notch, a stake is driven in near the bank, with its top exactly level with the crest. When the water flows over the weir, the depth of the water flowing over the crest is equal to the depth of water over the top of the stake, which depth can be measured with an ordinary rule.

Knowing the depth of water over the stake, refer to Table at the right, and note

is POWER

the amount of water passing over one foot length of the weir. Multiply this quantity by the length of the weir in feet and the answer will be the total flow in cubic feet per second.

In making the notch, certain dimensions must be used. Its length or width should be between 4 and 8 times the depth of water flowing over the crest of the weir. The pond back of the weir should be at least 1½ times wider than the notch, and of width and depth so the flow will not be more than 1 ft. per second. The water level on the downstream side must not be less than 8 inches below the weir crest. Care must be taken so air will be admitted freely between the falling sheet of water and the weir board.

Assume for example, a weir 6 ft. long with a depth of 12 inches of water flowing over it. Then from the table at right, the flow per foot of length of weir is found to be 3.24 cubic feet per second. Thus the total quantity of water flowing over the weir is 6 x 3.24 = 19.44 cubic feet per second.

This table is based on a weir having end contractions and with the length of weir 6 times the depth of water over the weir. When the length is 4 times the depth multiply tabular figures by 0.992. For a weir length 8 times the depth multiply tabular figures by 1.004.

Table Showing the Quantity of Water Passing Over Weirs in Cubic Feet per Second for each Foot of Length of Weir for Depth over Weir from 3″ to 20⅞″

Depth over Weir in Inches	0	⅛	¼	⅜	½	⅝	¾	⅞
3	.40	.43	.46	.48	.51	.54	.57	.59
4	.62	.65	.68	.71	.74	.77	.81	.84
5	.87	.90	.94	.97	1.00	1.04	1.07	1.11
6	1.14	1.18	1.22	1.25	1.29	1.33	1.36	1.40
7	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72
8	1.76	1.80	1.85	1.89	1.93	1.97	2.01	2.06
9	2.10	2.14	2.19	2.23	2.28	2.32	2.37	2.42
10	2.46	2.51	2.55	2.60	2.65	2.70	2.74	2.79
11	2.84	2.89	2.94	2.99	3.04	3.08	3.13	3.18
12	3.24	3.29	3.34	3.39	3.44	3.49	3.54	3.59
13	3.65	3.70	3.75	3.81	3.86	3.91	3.97	4.02
14	4.07	4.13	4.18	4.24	4.29	4.35	4.41	4.46
15	4.52	4.58	4.63	4.69	4.75	4.80	4.86	4.92
16	4.98	5.04	5.10	5.16	5.22	5.27	5.33	5.40
17	5.45	5.51	5.57	5.63	5.70	5.76	5.82	5.88
18	5.94	6.00	6.07	6.13	6.19	6.25	6.32	6.38
19	6.44	6.51	6.57	6.63	6.70	6.76	6.83	6.89
20	6.96	7.02	7.09	7.16	7.22	7.29	7.36	7.42

FRICTION LOSS IN NEW RIVETED-STEEL PIPES PER 1000 FEET

H = LOSS IN FEET HEAD   Q = DISCHARGE IN CUBIC FEET PER SECOND

Pipe Dia.		Velocities in Feet per Second										
Inches		2	3	4	5	6	7	8	9	10	11	12
6	Q	0.39	0.59	0.79	0.98	1.18	1.37	1.57	1.77	1.96	2.16	2.36
	H	4.10	8.58	14.62	22.10	31.00	41.22	52.80	65.70	79.90	95.40	112.00
8	Q	0.70	1.05	1.40	1.74	2.09	2.44	2.79	3.14	3.49	3.84	4.19
	H	2.91	6.15	10.50	15.85	22.23	29.50	37.85	47.10	57.30	68.40	80.25
10	Q	1.09	1.63	2.18	2.72	3.27	3.81	4.36	4.90	5.45	6.00	6.54
	H	2.24	4.74	8.09	12.20	17.13	22.74	29.17	36.30	44.13	52.75	61.95
12	Q	1.57	2.36	3.14	3.93	4.71	5.50	6.28	7.07	7.85	8.64	9.43
	H	1.81	3.83	6.53	9.86	13.83	18.36	23.60	29.31	35.60	42.60	50.00
14	Q	2.14	3.21	4.27	5.34	6.41	7.48	8.55	9.62	10.68	11.76	12.82
	H	1.51	3.20	5.46	8.25	11.58	15.35	19.70	24.52	29.80	35.60	41.85
16	Q	2.79	4.19	5.59	6.98	8.38	9.78	11.17	12.57	13.97	15.36	16.76
	H	1.29	2.74	4.67	7.05	9.90	13.13	16.85	20.96	25.50	30.90	35.75
18	Q	3.53	5.29	7.06	8.84	10.60	12.36	14.12	15.90	17.66	19.43	21.20
	H	1.13	2.40	4.07	6.16	8.45	11.47	14.70	18.31	22.20	26.55	31.20
20	Q	4.36	6.55	8.73	10.91	13.09	15.28	17.45	19.63	21.82	24.00	26.18
	H	1.00	2.11	3.60	5.44	7.63	10.13	13.00	16.17	19.65	23.48	27.57
22	Q	5.28	7.92	10.57	13.20	15.85	18.48	21.12	23.76	26.40	29.04	31.68
	H	0.89	1.89	3.22	4.86	6.83	9.06	11.62	14.47	17.60	21.00	24.68
24	Q	6.28	9.43	12.56	15.70	18.85	22.00	25.14	28.25	31.41	34.56	37.70
	H	0.80	1.71	2.91	4.40	6.16	8.18	10.50	13.07	15.88	18.96	22.30
26	Q	7.38	11.06	14.75	18.43	22.12	25.80	29.50	33.17	36.87	40.55	44.25
	H	0.73	1.56	2.65	4.01	5.62	7.46	9.57	11.92	14.48	17.30	20.30
28	Q	8.55	12.83	17.10	21.38	25.65	29.94	34.20	38.48	42.76	47.04	51.32
	H	0.67	1.43	2.43	3.67	5.15	6.84	8.78	10.93	13.28	15.86	18.63
30	Q	9.82	14.73	19.64	24.55	29.44	34.37	39.28	44.17	49.10	54.00	58.91
	H	0.62	1.31	2.24	3.39	4.75	6.31	8.10	10.08	12.25	14.61	17.18
32	Q	11.17	16.76	22.35	27.92	33.50	39.10	44.70	50.26	55.85	61.45	67.03
	H	0.58	1.22	2.08	3.15	4.41	5.86	7.52	9.36	11.37	13.58	15.95
34	Q	12.61	18.92	25.22	31.52	37.82	44.13	50.45	56.75	63.05	69.36	75.66
	H	0.54	1.14	1.94	2.92	4.10	5.44	6.99	8.70	10.57	12.62	14.83
36	Q	14.14	21.21	28.28	35.35	42.42	49.49	56.56	63.63	70.70	77.77	84.84
	H	0.50	1.06	1.81	2.74	3.84	5.10	6.55	8.15	9.90	11.81	13.90
38	Q	15.75	23.63	31.50	39.37	47.25	55.12	63.00	70.88	78.76	86.60	94.50
	H	0.47	1.00	1.70	2.57	3.61	4.79	6.14	7.64	9.30	11.10	13.04
40	Q	17.45	26.17	34.90	43.62	52.36	61.10	69.80	78.52	87.26	96.00	104.70
	H	0.44	0.94	1.60	2.42	3.40	4.51	5.79	7.20	8.76	10.45	12.28
42	Q	19.24	28.86	38.48	48.10	57.72	67.34	76.96	86.58	96.20	105.80	115.40
	H	0.42	0.89	1.51	2.29	3.21	4.26	5.46	6.81	8.27	9.88	11.60

For loss in wood-stove pipe multiply tabular figures by 0.80.
For loss in cast-iron pipe (new) multiply tabular figures by 0.80.
For loss in old riveted pipe multiply tabular figures by 1.20.

HAVING determined the flow in cubic feet per second, the next important matter is to determine the power available.

Assume, for example, a full load efficiency of 83.7%. The formula for horsepower delivered to the generator shaft becomes: H.P. = .095 x H x Q; in which "H" is the net effective head at the turbine in feet, and "Q" is the discharge in cubic feet per second.

"Q" is easily found in the Weir Table on preceding page (providing a weir measurement has been taken). The net head "H" is equal to the static head less all friction losses, from the intake (forebay) to the impulse turbine nozzle.

The distance from center-line of turbine nozzle to the tail (discharge) water level, must also be added to friction losses and deducted from the static head. This information is not readily available and for preliminary approximations, it may be roughly estimated or entirely omitted.

The total losses in the penstock must include the friction losses in the pipe and losses due to pipe bends and whatever loss occurs at the entrance.

For example: If a new riveted steel pipe is installed and laid on an even slope with a flared entrance, losses will be due to straight pipe friction and can be easily determined by referring to the Friction Table, Page 30.

To illustrate: Supposing the static head, or vertical distance between the forebay and the tail water level, is 500 feet. Let us assume that a "weir" measurement has been taken and it is found that the flow is 6 cubic feet per second. Suppose, again, that the penstock is 2000 feet long, on even slope with flared entrance. Estimate losses at 5% of the static head. This would result in .05 x 500 = 25 feet. The power available at the generator shaft would be .095 x 475 x 6 = 271 H.P.

Should the turbine nozzle be located 5 feet above tail water level, the friction loss to be used in selecting the penstock would be 25 – 5 = 20 feet. The loss for 1000 feet of penstock is 10 feet. By referring to friction loss tables on opposite page, it will be seen that for Q = 6 and H = 10, a 14″ penstock is required. The velocity, by interpolation, is 5.62 feet per second.

The matter of judgment enters into the selection of the size of impulse turbine best-suited to perform a certain job, despite the fact that the "weir" measurement will determine the flow of the stream. The reason for this is—what size of turbine will be most efficient, whether flow is maximum or minimum! If pondage is available, turbine capacity may be increased, by making a careful study of the reservoir and its relation to load demand.

It is apparent with such important factors as amount of water available, height of head, friction losses to be settled that specific recommendations for a contemplated impulse turbine installation cannot be made until after a most careful study has been completed. Our Engineering Department is placed at your disposal for solving your problem by the selection of the Smith Impulse Turbine suited to your individual requirements.

Power by SMITH

THIS phrase represents the sum-total of more than sixty years of experience in solving Water Power Problems and in building the machinery needed to produce power at low cost. As such it is your assurance of value and satisfaction from any Smith-Built Equipment you purchase.

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S. MORGAN SMITH COMPANY

YORK, PENNSYLVANIA

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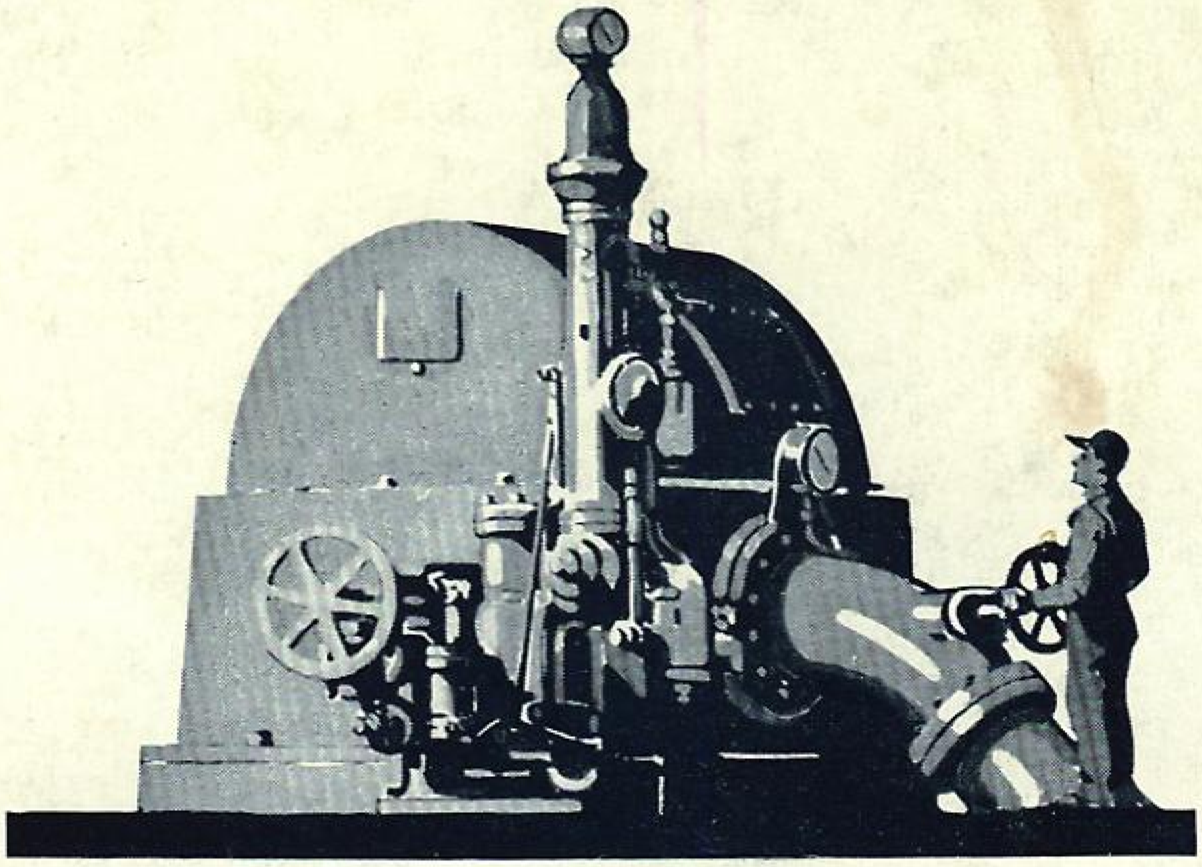

Impulse Turbines

by SMITH