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REPORT ON THE
HYDRAULIC ANALYSIS OF THE PUMP STATIONS AND PIPELINES
FOR THE
DOMESTIC WATER PROJECT - NORTH JORDAN
THE HASHEMITE KINGDOM OF JORDAN
JORDAN VALLEY AUTHORITY
EGMC - PIPELINE AND TREATMENT PLANT DESIGN

REPORT PREPARED FOR THE
UNITED STATES DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C.

BY
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BOULDER, COLORADO
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PROJECT NO. 278-0181
CONTRACT NO. NEB-0181-C-00-1023-00
JORDAN

INTRODUCTION

In accordance with my agreement with USAID, I left Boulder, Colorado on Wednesday, March 4 and spent Thursday and Friday at the USAID office in Washington to complete contractual arrangements and to obtain a Visa. I left Washington on Saturday and arrived in Amman, Jordan on Sunday evening, March 8. Upon completion of my scheduled 4 day assignment in Jordan, I left Amman on Thursday, March 12 and arrived in Boulder, Colorado on Friday evening, March 13.

On Saturday morning March 14 I received a long distance phone call from Dr. Munther J. Haddadin of JVA. He informed me that he was planning on scheduling a joint meeting of the USAID Consultants with Stanley Consultants Inc. and Boyle Engineering Corporation in Chicago on March 18 and 19 for further joint discussions. He asked if I could be present for the March 19 meeting. This proposed meeting was later confirmed by Mr. L. Titus and Mr. F.W. Montanari. In order to attend this meeting in Chicago I left San Francisco before noon on March 18 and arrived in Chicago in the evening. After the meeting in Chicago on Thursday March 19 I left Chicago in the afternoon and returned to my home in Boulder, Colorado late Thursday evening.

REVIEW OF DOCUMENTS

About the middle of February I received the following documents for study from Stanley Consultants:

Part 1 Southern Region - Technical and Financial Assessment, dated August 22, 1979

Southern Region - Design Memorandum, dated November 19, 1979

Addendum to Southern Region - Design Memorandum, dated January 25, 1980

These reports and several others were studied and discussed briefly with Mr. F.W. Montanari and other members of the USAID staff when I was in Washington prior to leaving for Jordan.

In Amman, on Monday, March 9 I was taken on a brief afternoon inspection tour of the Jordan Valley by Mr. Aied S. Sweis, Civil Engineer of USAID. Mr. Sweis pointed out the latest proposed locations of the major pumping plants, treatment plant, and approximate alignment of the pipelines. Later I also had an opportunity to study additional documents and reports by Stanley Consultants in the USAID office in Amman. These included the following:

Tender Documents for Contract No. 1 - Pipeline, Volume 1 of 2 dated May, 1980

Tender Documents for Contract No. 3 - Pump Stations, Volumes 1 and 2, dated May, 1980

Plans for Contract No. 1 - Pipeline, dated May, 1980

Plans for Contract No. 3 - Pump Stations, dated May, 1980

In Amman I also had informal discussions with Mr. Glenn Wagner, Consultant to USAID for the water treatment plant and also with the following members of the USAID staff:

Mr. Thomas A. Pearson, Capital Resources Development officer
Mr. Albert A Karian, Chief Engineer
Mr. James G. Cassanos, Sanitary Engineering Consultant

MEETING WITH JVA

On Wednesday, March 11 together with Mr. Pearson, Mr. Cassanos, and Mr. Wagner a meeting was held with the following officials from the Jordan Valley Authority in the JVA offices:

Mr. Omar Abdullah Dokhgan, President
Dr. Munther J. Haddadin, Senior Vice President

At this meeting I summarized my evaluation of the proposed pumping stations and pipelines as noted below and suggested some additional studies of the pumping plants and pipelines to assure greater reliability, simplicity, safety and possibly lower cost.

CHICAGO MEETING

At the March 19 meeting in Chicago Mr. Titus of Stanley Consultants was present with about 5 or 6 other engineers from Stanley Consultants and Boyle Engineering. Also present were Mr. Montanari, Mr. Wagner, Mr. Dokhgan and Mr. Haddadin.

PRESENT INSTALLATION

From a study of the documents and meetings held previous to the Chicago meeting, it was my understanding that based on geotechnical investigations it had been definitely decided that the water treatment plant would be moved out of the Jordan valley to the top of the escarpment because of poor foundation conditions and other considerations. At the meeting in Amman with JVA Mr. Wagner proposed keeping the treatment plant in the valley and explained his reasons for doing so. At the Chicago meeting this subject had been discussed in detail on the previous day prior to my arrival. It is my understanding now that the treatment plant may be located either in the valley or out of the valley on the top of the escarpment. This alternative has some significance in the final analysis of the pumping plants 1 to 4 with respect to the choice and reliability of surge control devices relative to raw water or treated water being pumped. To a minor extent it also has an effect on the friction losses in the pump discharge lines.

The presently proposed pumping systems as I understand them are as follows:

Intake Pump Station, Raw water, TDH 18 meters, 125 horsepower motors
Pump Stations 1 to 4, Raw water or treated water depending on the location of the treatment plant, TDH 285 meters, 16 pumps for the 4 stations, 1750 horsepower motors
Pump Station 5, Treated water, TDH 198 meters, 4 pumps, 1250 horsepower motors
Pump discharge line diameter for pump stations 1 to 4 is 1.2 meters
Surge protection for pump stations 1 to 4 to be provided by hydro-pneumatic chambers

EVALUATION OF PUMPING STATIONS AND PIPELINES

My evaluation of the presently proposed pumping stations and pump discharge lines is as follows:

1. The current designs for both features are based on conservative engineering practice. However, for the 6 pump stations it requires numerous operation and maintenance personnel and a considerable number of intermediate facilities in order to coordinate the flow through the various stations.

2. There are other practical and dependable alternatives for effective surge control at Pump Stations 1 to 4 which should be considered in addition to hydro-pneumatic chambers. These are described in my book "Waterhammer Analysis".

3. When it is found necessary to increase the minimum steel pipe shell thickness aside from the internal pressure requirements, an alternate pipe material such as ductile iron pipe should also be considered. This pipe material would be especially applicable for the Intake Pump Station discharge line and the upper reaches of the discharge line for Pump Station 5. The 1.2 meter diameter ductile iron pipe is now available with working pressures up to 350 psi. All pressure ratings for ductile iron pipe have an ample thickness and therefore an ample margin of safety against collapse due to sudden sub atmospheric pressure shocks associated with pump power failures.

Such pipes are now being installed at the MITLA pumping plant complex in KUWAIT with the 1.0 meter diameter size. The 1.2 meter diameter ductile iron pipe was also installed for the DESCOBERTO pump station discharge line in BRAZILIA, BRAZIL. This 13.5 kilometer line has been tested for surges due to power failure and has been in operation for over 5 years.

4. The hydro-pneumatic tanks at Pump Stations 1 to 4 should be protected with suitable enclosures because of the hazardous nature of exposed large high pressure air vessels. There are also additional safety features such as emergency probe levels which should be installed in the event of the failure of various devices which are associated with this method of surge protection, especially if raw water is pumped.

5. With respect to the 16 pumps and motors in Pump Stations 1 to 4 it should be noted that these are not off-the-shelf items as has been presumed by JVA. These are specialty items which must be designed specifically for this project. The design of such pumps and motors are well within the experience and capability of many worldwide manufacturers. With regard to the spare pump and motor for these 4 pump stations, I doubt that a spare pump and motor could be replaced in one or two days in an emergency as has been stated in the reports.

6. The pump discharge check valves at these 4 pump stations will require oil dashpots or snubbers to prevent damage due to severe check valve disc slam upon a power failure at the pump motors. Without these dashpots the check valve slam will be very violent with the hydro-pneumatic chambers present and could rupture the check valve body. This results from the fact that the time of flow reversal at the pumps upon a power failure will be very short due to the presence of the hydro-pneumatic chambers and therefore the check valve will be required to close almost instantly.

At the California State Water Project it was necessary to pump large amounts of water out of the San Joaquin Valley over the Tehachapi Mountains with a pump lift of nearly 2000 feet. This was accomplished at the Edmonston Pumping Plant with 14 single lift 4 stage pumps, each driven with 80,000 horsepower motors. A number of multiple lift alternatives were studied in detail and were subsequently discarded in favor of the single lift concept which was considered to be the safest and most reliable. This pumping plant has now been in successful operation for about 15 years and is the key pumping plant for the whole California State Water Project.

RECOMMENDATIONS

Based on the above comments my recommendations for possible alternatives for the project are as follows:

1. Study the possibility of reducing the number of Pump Stations 1 to 4 to two pump stations by combining Stations 1 and 2 and by combining Stations 3 and 4. All of the pumps in both stations could have the same TDH and hence would require a single design. Such high lift pumps have been used elsewhere as indicated on the attached list.

2. Install a spare pump at each of these two pump stations.

3. Study alternate methods for surge control. For example, at the Edmonston Pump Station noted above, the control of pressure surges and reverse rotation of the pumps upon a power failure were accomplished with a two speed discharge valve closure. No pump check valves or hydro-pneumatic chambers were required.

4. The initial power surge requirement at shutoff head for starting multi stage pumps with submerged intakes and dis-

charge valve closed is about one-half of that required for full flow pumping. This favorable power characteristic can be used to optimize the number and size of the pumps required at each pumping plant to limit the power surge on the electrical grid to an acceptable value.

5. The required pump submergence for multistage pumps is based on the head delivered by the first stage pump impellers. With a double suction intake for the first stage and 4 to 5 stages on each pump as required, there should be no requirement for additional pump submergence with the higher head pumps.

CONCLUSIONS

With 2 pump stations eliminated, a lesser number of operation and maintenance personnel will be required, fewer equalizing reservoirs and auxiliary equipment and with a standby pump installed at each of the 2 pump stations the pumping system will be more dependable for maintaining the required flows.

John Parmakian

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April 6, 1981

Table I. Remarkable Pumped Storage Plants in Europe

No.	Year	Country	Name of Plant	Head, Meters	Turbines—Number Output: Type	Turbines—Number Output: Mw	Pumps—Number Input: Type	Pumps—Number Input: Mw	Speed	Shaft	Coupling Starting
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	1930	D	Herdecke	156	F	4×35=140	2d	4×25=100	300	h	G, ST
2	1931	D	Waldeck	300	F	4×30=120	2d	4×21=84	500	h	G, HC
3	1931	D	Häusern	190	F	4×27.5=110	2s	4×21=84	333	v	G, HTC
4	1933	F	Lac Noir	120	F	4×30=120	1s	3×18+1×11=65	272	v	R
5	1943	D	Witznau	230	F	4×55=220	2s	4×29=116	333	v	G, ST
6	1948	CH	Etzelwerk	480	P1-2	6×14.5=87	5s	2×15=30	500	v	FC
7	1949	I	Ponale	600	P1	1×35	5s	1×30	500	h	P
8	1950	I	Provvidenza	265	F	3×50=150	2d	2×44=88	450	h	G
9	1950	I	Cotilia	145	F	2×30=60	1d	2×27=54	337.5	h	R
10	1951	CS	Dobsina	275	F	2×10.5=21	2d	2×8=16	1,000	h	G
11	1951	D	Waldshut	160	F	4×44=176	2s	4×17=68	250	h	G, ST
12	1952	A	Ranna	180	F	1×13	1d	1×13	750	h	G
13	1952	A	Rodund	330	F	4×42.5=170	2d	2×40=80	500	h	G, ST
14	1953	S	Lettalven	200	F	2×20=40	1d	2×20=40	500	h	G
15	1954	F	Pragnères	400			3d	2×9=18	1,000	h	
16	1954	CH	Oberaar	490	P2-2	1×31			375	h	
				400			2d	1×18	1,000	v	
17	1955	A	Limberg	380	F	2×57=114	2d	2×60=120	500	h	G, BT
18	1955	CH	Peccia	380	P2-2	2×23.5=47			300	h	
							2s	2×10.5=21	1,000	h	
19	1955	D	Reisach	180	F	3×34=102	2d	3×27.5=82.5	333	h	G, ST
20	1956	A	Ottenstein	60	F	4×10=40	1s	3×9=27	250	v	G, SM
21	1956	N	Brattingfoss	115	F	1×10	1d	1×10	428	h	G
22	1958	CH	Motec	620	P2-4	3×23=69	3s	1×25	750	h	G
				130			1s	1×6.7	750	h	G
23	1958	D	Geesthacht	80	F	3×43=129	1d	3×31=93	214	h	G
24	1958	D	Happurg	200	F	4×36=144	2d	4×34=136	375	h	G, ST
25	1958	A	Lünersee	980	P1-4	6×46=276	5s	6×43=258	750	(h) V	G, HTC
26	1960	D	Tanzmühle	130	F	1×29	1d	1×22	375	h	G
27	1960	CH	Stafel	232		3×8.2=24.6					
					RPT		1d		1,500	h	
				212				3×7.6=22.8			
28	1961	I	Guadalami	180	F	2×31+	2d	2×28=56	428	h	G
					F	1×20=82			500	h	
29	1961	CH	Ferrera	520	F	3×63=189	2s	3×21=63	750	h	G, FB
				40	RPT	2×1.7=3.4	2s	2×1.8=3.6	600	v	
30	1961	GB	Ffestiniog	305	F	4×74=296	2d	4×70=280	428	v	G, FB
31	1961	D	Leitzach	125	F	2×24=48	1d	2×19=38	428	h	G
32	1961	I	Provvidenza	265	RPT	1×50	1s	1×50	375	v	
33	1961	F	Hospitalet	775	P2-4	3×34=102			750	h	
				535	P2-4	1×14			750	h	
				300			2d	2×24=48	750	h	G
				1,000	P2-4	3×87=261			600	h	
34	1962	CH	Tierfehd	480	P1-2	2×20=40			428	h	
				500			3s	2×17=34	1,000	h	
35	1962	L	Vianden	270	F	9×100=900	2d	9×70=630	428	h	G, ST
				270	RPT	2×1.7=3.4	1s	2×1.7=3.4	3,000	v	
36	1962	P	Alto Rabagao	180	F	2×45=90	1s	2×29=58	428	h	R
37	1962	I	Villa Gargnano	410	F	2×65=130	2d	2×65=130	600	v	G
38	1963	D	Erzhausen	280	F	4×59=236	2d	4×55=120	428	h	G, ST
39	1963	CH	Arolla	310			2d	2×14.2=28.4	1,500	h	
							2s	2×7.1=14.2	1,500	h	
40	1963	Glems		290	F	2×41=82	2d	2×33=66	600	h	G, ST
41	1964	CH	Z'Mutt	470			2d	2×27=54	1,500	v	
				305			2d	2×11=22	1,500	v	
				490		2×16=32			2×500	v	
42	1964	GB	Cruachan	350	RPT	4×100=400	1s	4×100=400	2×600	v	
43		D	Sackingen	425	F	4×80=320		4×62=248		h	
44		D	Strittmatt	220	F	4×36=144		4×32=128		h	
45		D	Wehr	600	F	8×87=696		8×77=616		h	
46	1963	E	Valdecanas	250	RPT	3×80=240	1s	3×80=240	600	v	

Note:

Column III, Countries: A = Austria, CH = Switzerland, D = Germany, F = France, GB = Great Britain, I = Italy, L = Luxembourg, N = Norway, P = Portugal, S = Sweden, E = Spain.

Column VI, turbine type: F = Francis, P = Pelton; first figure gives the number of runners per unit, second figure gives the number of jets per unit, e.g. P2-4 = Pelton turbine with 2 runners and 4 jets; RPT = reversible pump-turbine; respective data for turbine and pump operation are listed in Columns VII and IX.

Column VIII, pump type: Figure gives the number of stages, s = single suction, d = double suction.

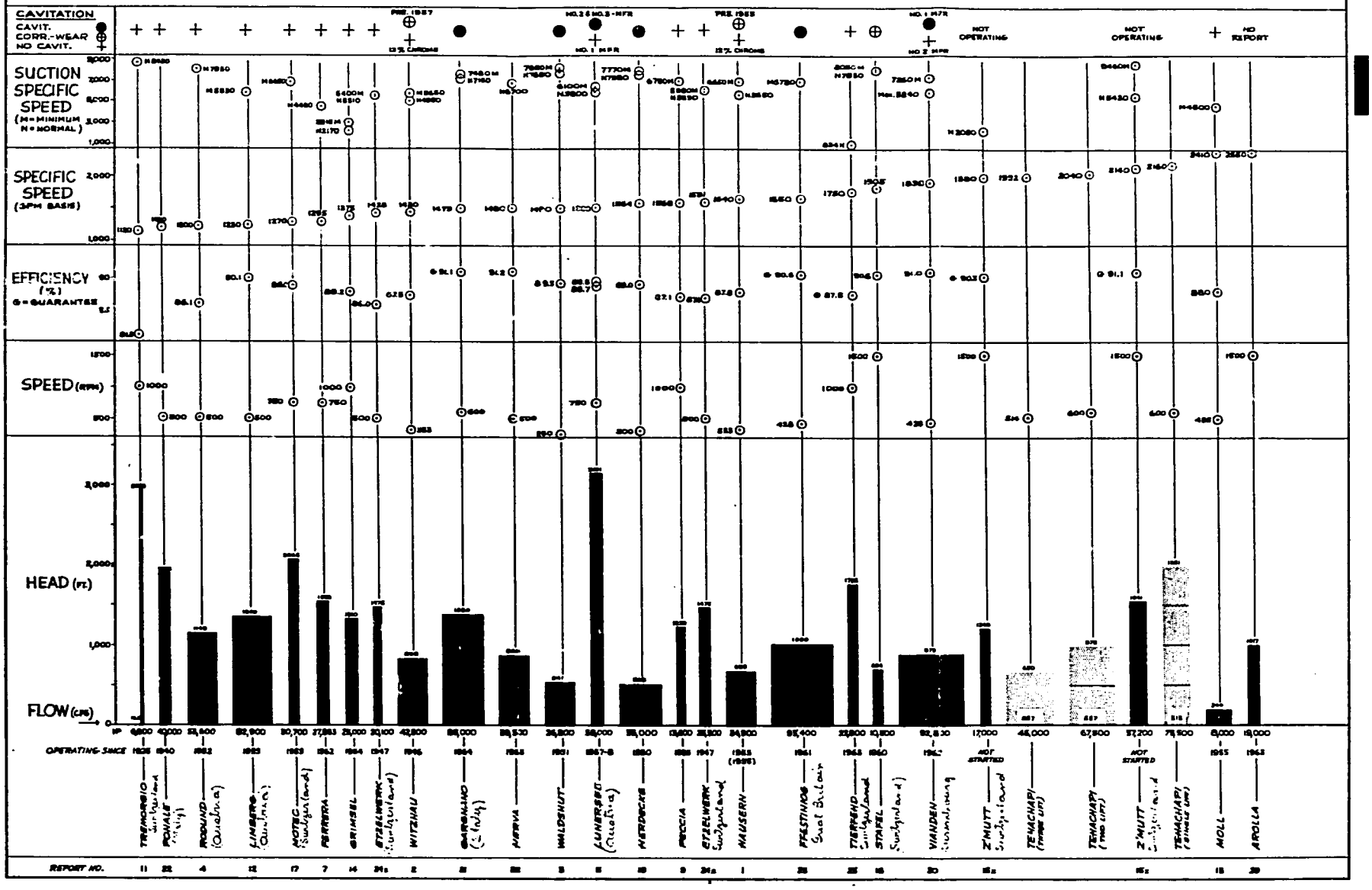
Column XI, shaft arrangement: h = horizontal, v = vertical.

Column XII, coupling and starting device: G = gear coupling, ST = starting impulse turbine, HC = hydraulic coupling, HTC = hydraulic torque converter, R = rigid coupled, P = pin coupling, FB = friction brake, BT = brake impulse turbine, SM = starting motor, FC = friction coupling.

Plants are identified by their respective number in Table I.

7. With feed pump, driven by impulse turbine.
12. With feed pump, driven by electric motor.
16. Tail water not identical for turbine and pump.
17. Refer to Fig. 5; units can be operated in "hydraulic short circuit."
18. With feed pump, driven by electric motor.
19. Refer to Fig. 2.
22. Refer to Fig. 4.
23. Extension planned.
24. Hydraulic short circuit planned.
25. Three feed pumps, driven by electric motor, discharging to buffer basin; refer to Fig. 6.
26. Same upper reservoir as 19.
27. Refer to Fig. 14.
29. Refer to Fig. 3.
32. Extension of 8.
42. Two units of 500 rpm, two units of 600 rpm.
43, 44, 45: Hotzenwald Scheme; approximate data (in planning stage).

BEST AVAILABLE DOCUMENT

TEHACHAPI PUMPING PLANT

COMPARISON WITH INSTALLATIONS IN EUROPE