GUIDE FOR OPERATION OF CAVITATION TUNNEL, DRAINAGEPUMPS OF EXPERIMENTAL TANKS AND WASTE WATER.

Report Nr. 116

Shipbuilding Laboratory.

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August 1962.

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A. Introduction.

The Delft cavitation tunnel has been built as a scale for a much larger tunnel by "Kempf und Remmers", Hamburg.The tunnel was used at the N.S.M.B.-Wageningen for the development of the system by Professor van Lammeren for the excitation of a non-uniform velocity distribution in the measuring section. After having accomplished this tank, the tunnel was sold to the University of Delft.

The tunnel was designed for the investigation of ships' model propellers at relatively low Reynolds numbers. Because of the application of rather high rotation velocities the stability of flow was less important, moreover a relatively large cavitation number related to the inflow velocity could be accepted.

In the Shipbuilding Laboratory the need was felt to investigate hydrofoil profiles, in which case the flow condition is of much more importance. In the first place a much lower cavitation number of the main flow is required. Secondly a larger velocity is needed. Of much importance, especially with moving foils is, that velocity and cavitation number are constant and that they are not subjected to periodic variations. The requirements of the tunnel are much increased.

When the Laboratory building was extended in 1960-1961, the opportunity was used to improve the cavitation tunnel and increase its space. Now the tunnel installation is accommodated in separate rooms at the first floor and ground floor and in part of the cellar beneath.

In the cellar, mentioned above, room has been found to accommodate also several other auxiliaries as the Ward Leonard generator for the propulsion of the larger towing carriage, a drainage pump for both experimental tanks and the wave maker ventilator.
In this manual the operation of the drainage pump and a set of waste water pumps are included, as their use is in some respect connected with the operation of the cavitation tunnel.

B. The Cavitation Tunnel.

Notes which are of value for the investigator using the cavitation tunnel.

1). Hydraulic variator.

The original 9-step gearbox which served to alter the number of revolutions of the axial flow pump which is driven by a 3 phase A-C motor, is replaced by a hydraulic variator to give continuous velocity control. Its data are:

Maker: Carter Hydraulic
Type: 6 A
Power: 20 hp.
Reduction: 1:0 to 1:1 continuous
Total transmission of Vee-drive 3000 r.p.m to 0 or 700 r.p.m.
Supplied by: v. Gelder Cie., Rotterdam.

The reduction is altered continuously by means of an electric servomotor. Originally the whole range of the variator was used, but this proved to be inefficient as a result of the difference of pumploading with the alteration of parts of the circuit.

By interchanging the secondary Vee-drive disks the range is increased, but as a result it is now important to take care that the allowed current in the propulsion motor is not exceeded. The maximum value is 28 A. The value of the consumed current can be read at a current meter which is situated in the lefthand panel of the FK-case in the measuring-room. The meter is equipped with a contact which activates a claxon. The claxon can be switched off with switch no. 13.

2). Extension of vertical tunnel legs.

The use of very low cavitation numbers in the measuring section, originally caused cavitation of the pumpimpeller. This was evident, as the velocity fell off when the vacuum was increased. Also the re-entrance of cavitation bubbles in the measuring section was much too inconvenient.

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With the extension of the laboratory building, the static head on the impeller was raised by adding longer vertical parts to the tunnel. For financial reasons the lengthening was restricted. The lower sections with the propulsion installation was placed parterre, but the possibility was taken into account, to make a later extension down into the cellar. For this reason it is advisable to keep the necessary space in the cellar free.

3.. Filter section.

With earlier experiments much inconvenience was met with dirt particles which attached to the model at the stagnation points of the flow. In order to reduce this difficulty somewhat, a small part of the "downcomer" was made removable with a somewhat increased sectional area. In this part a gauze filter was placed which catches most of the dirt. A possible advantage is the property, that also air bubbles are held for some time; thus more air will be resolved into the water. The increased resistance of the circuit is taken into account. To be able to change or clean the filter easily, the adjoining bend containing the propulsion pump can be lowered easily.

4.. Storage tank, water supply and drainage.

For quick interchangement of models and for repair work in the measuring section, in the cellar a storage tank was placed with a capacity of 2 m^3 (~ 500 U.S. gallons).

The transport of the water to and from the storage tank is controled by electrically operated pneumatical valves and a centrifugal pump ("opvoerpomp") having a capacity of 24 m^3/hour (6300 U.S. gall/h.) and a pressure head of 15,5 m water (50 ft) (drawing no. 60382-2 by Heemstede Obelt N.V.).

The air pressure for the valves is maintained by a compressor (supplied by v. Heemstede Obelt N.V.) which stands by continuously.

4.1. Use of storage tank.

With normal use of the storage tank the switch marked: AVT/HAND at FK-16 in the cellar must be pointed at: "HAND". The switches for operation of the storage tank are situated at:

1). Board FK-16 in the cellar.
2). Board FK in the measuring room.
3). The operation-desk in the measuring room.

These three switchboards work independently from each other. The marks near the switches and sign-lamps and their functions are listed below. (see figure 1).

4.1.1. Drainage valve open. (Waterafvoer "open").

a). The magnetic valve (1) in the air supply conduit to the pneumatic valve (2) opens, which in its turn opens this valve (2).
b). The first micro switch on valve (2) closes and signals valve: "open" to the panels. When the valve travels, both signs: "open" and "dicht" (closed) are illuminated.
c). When valve (2) is fully open, micro switch nr. 2 opens and extinguishes sign "dicht" (closed").
d). Water from the tunnel flows into the storage tank until the upper float switches the magnetic valve (1) to close again and to open to atmospheric pressure. Valve (2) closes by spring pressure.
e). The second micro switch on valve (2) is closed and signals valve: "dicht" (closed) to the panels.
After total closure of valve (2) the first micro switch is opened again and the signal valve "open" is extinguished, which ends the operation.

Thus, the drainage is ended automatically when the storage tank is full.

4.1.2. Drainage valve closed. (Waterafvoer "dicht").

The magnetic valve (1) is closed and opened to atmospheric pressure. Valve (2) is closed by spring pressure (see 4.1.1. d and e).

By this operation drainage is stopped manually, which is necessary when the storage tank has not to be totally full or when the upper float is defective.

4.1.3. Water supply valve "open". (Wateropvoer afsluiter "open").

a). The motor of the supply pump (4) is started and the sign: "opv. p" is illuminated.

b). The magnetic valve (5) in the air conduit to the pneumatic valve (6) connects this valve with the compressed air; valve (6) opens.

c). The first switch on valve (6) closes and signals: "open" to the panels.

d). When valve (6) is fully open the second switch is opened, which extinguished sign: "dicht" (closed).

e). The water is now pumped out of the storage tank to the cavitation tunnel until the minimum float switches the pump off; the sign: "opv. p" is extinguished and the magnetic valve (5) in the air conduit is closed to high pressure and opened to atmosphere. Now valve (6) closes.

f). The second switch on valve (6) closes when the travel of the membrane begins, which illuminates sign: "dicht" (closed). The first switch opens when the valve is closed and extinguished sign "open" on the panels.

Thus, the water supply stops automatically when the storage tank is empty.

Note:

At the time of writing of this report, the lower ("minimum") float has never operated properly as its position is too low and its case is too narrow. When the tank is nearly empty, air is sucked into the pump and the water flow is stopped, without closure of the valve and stopping of the pump. Both float cases proved to be too narrow.

4.1.4. Supply valve closed. (Afsluiter wateropvoer "dicht").

See 4.1.3. e and f. This knob is used when the tunnel is full before the storage tank is empty, or when the "minimum" float is defective.

4.2. Replacement of water.

Supply of fresh water to the empty system occurs by way of the manual valve (8) which is situated near the ceiling of the cellar. After opening of this valve, water enters freely into the storage tank.

When the water surface reaches the lower float (7) the supply pump (4) and the supply valve (6) are deblocked and can be put into service with the knob: "opvoerafsluiter open". The transport of water from the storage tank to the tunnel occurs much faster than the supply of fresh water, so that the storage tank is emptied periodically. With a good working lower float, the transport is stopped relatively soon. (See 4.1.3. e and f).

The filling of the tank with fresh water takes some 20 minutes, whereas the transport with open valve (8) takes some 7 minutes and 5 minutes with closed fresh water supply.

For a complete refill of the tunnel, about 3 times the volume of the storage tank is needed. In order to ensure a smooth refill, an automatic periodic supply system was designed. (It's possible operation depends upon improvement of the floats)

The supply switch in the cellar on panel FK 16 has now to be set on "out". In this case the upper float will operate the supply pump and the supply valve each time the storage tank is full. When the tunnel is full:

a). The supply pump has to be stopped (see 4.1.4.),
b). the fresh water supply valve (8) has to be closed,
c). the switch on FK 16 has to be set back in the position "hand".

4.3. Complete drainage.

When the tunnel has to be emptied, the manual valve (9) in the conduit to the sewer must be opened. To empty the storage tank, the supply pump (4) has to be put in use with open sewer valve (9).

5. Hydrostatic journal bearing.

As the cavitation number in the tunnel was disturbed by a 4.3 c/sec. disturbance, which was thought possibly to originate in the loudly resounding rubber journal bearing of the axial flow pump situated just in front of the impeller, the rubber bearing was interchanged by a modern hydrostatic bearing with capillary compensation, which was made at the own workshop (see drawing no. 896). The pressure for the bearing is maintained by a gear pump:

Manufacturer: Maag - Zürich
Type: HP 35
Capacity: 6 l/min. at 12 kg/cm^2 and 720 r.p.m.
Max. r.p.m.: 1500
Max. pressure with water: ~30 kg/cm^2
Supplier: Plaisier - Den Haag.

The prevent shaft and bearing from damage when the hydrostatic pressure falls out, several securities are incorporated in the circuit of the pump:

a). A filter to prevent the capillaries from stopping up.
b). An air vessel to get a retardation in the decrease of pressure in the bearing, so that sufficient pressure is maintained during the slowing down period of the impeller.
c). A double pressure switch with the functions:
   1e. Stopping of the axial flow pump when the pressure reaches a minimum value and resetting the variator.
   2e. Blocking the axial flow pump during the time that the pressure in the air vessel is insufficient.
d). As a check in both tunnel rooms a manometer is placed against the wall; these measure the hydrostatic pressure at the inflow end of the capillaries. This pressure must amount to 12 or 13 atmospheres.

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The switch which operates the high pressure pump is situated on the FK panel in the measuring room. (1st floor).

6. Water purification installation.

In order to clean the water and to decrease corrosion in the tunnel, a purification installation is placed in the cellar, which consists of:

6.1.1. A filter vessel type M 6.
Manufactured by: Nederlandse Waterzuiverings Mij., Amsterdam.
Filter material: Dolomite.

6.1.2. A "Wasserknecht" piston pump type WL 2500
Manufacturer: Loewe.
Supplier: Vihamij, Arnhem.

The water is drained off at the normal drainage conduit of the tunnel and is returned in the upcomer just above the first bend of the tunnel. It is hoped, that a slow circulation is induced in the tunnel during the purification.

The water can be purified during normal tunnel operation, but pressure disturbances occur, caused by the piston pump.

6.2. Rinsing.

The filter vessel must be rinsed each month in order to get rid of soil and to prevent the material from stopping up of the upper layer.

For this operation the valve in the return conduit to the tunnel is closed and the waste water is drained to the waste water pit via a hose.

Note:

The supply of waste water to the pit is too large to be drained off by one pump. When the water in the pit reached a certain level, a claxon in the laboratory is sounded and at the same time the second pump starts working. It is necessary that somebody is present to silence the claxon and to take care that the pit is not flooded.

6.3. Dolomite consumption.

The dolomite is consumed gradually, so once a year filling up is necessary.

7. Deaeration and vacuum system.

In the deaeration and vacuum system several change have been accomplished since the first installation of the tunnel.

7.1. Deaeration.

A good drainage of air bubbles is promoted by the construction of domes at three points which are high with respect to their surroundings:

a). At the lower conduit near the end of the diffuser behind the axial flow pump.

b). At the wide bend in front of the contraction to the measuring section. This is the place of the original dome.

c). At the end of the horizontal diffuser behind the measuring section.

The domes a) and b) are connected with dome c) by rising conduits. The latter dome being the one with the lowest static pressure, in which all bubbles are assembled.

It is planned to connect the inflow side of the hydrostatic bearing pump also with dome c) in order to prevent air from entering the high pressure pump.

7.2. Vacuum system.

7.2.1. Distribution panel.

The dome (7.1. c) with the lowest pressure is connected by means of two conduits with a distribution panel with 6 valves. In one of the conduits a pressure vent is placed to prevent the tunnel from overloading.

7.2.2. Vacuum pump.

The distribution panel is connected with the vacuum pump via an air vessel. Particulars of the pump are:

Make: Leybold - Cologne.
Type: VP 2.
Capacity: 2 m^3/h.
Power: 200 W.

The oil must be changed once a month and each time when the pump is flooded. Air vessel and pump are situated against the wall in the measuring section. The air vessel serves to prevent the pump from flooding. It must be drained off regularly.

7.2.3. Automatic vacuum control.

At the distribution panel a transducer for automatic vacuum control is placed, made by van Essen - Delft.

This is a simple pressure switch which in principle is meant for air. The transducer can be connected with dome 7.1. c with one of the two aforementioned conduits in which two condensing vessels are placed to deep the transducer free of water. The condensing vessels are situated at the sides of the tunnel in the lower tunnel room; they must be drained off regularly.

7.2.4. Operation.

The vacuum pump can be operated:

a. At the control desk (BL) by means of a turning switch signed "aut" (automatic), "uit" (stop) and "hand" (manual).
b. At the panel FK against the wall by means of two switches marked "aut" and "hand".

When the control desk is out of use, the knobs at the panel are used: the turning of knob "aut" starts the vacuum pump until a certain pressure is reached, which is present on the transducer When a larger range is needed, knob "hand" is used. When the control desk is used, both knobs on the panel must be turned in.

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8. Flow pump operation ("stromingspomp").

Before the axial flow pump (tunnel water propulsion) can be started, the hydrostatic bearing must be pressurized (see 5). All is clear when the red light above the "stop" knob on the desk is extinguished and when the manometer at the desk points at about 12 atmospheres(the pressuring takes about 3 to 10 minutes depending on the amount of air in the air vessel). Up to this moment, the propulsion motor is electrically blocked.

The axial flow pump can be started by means of the knobs "V" (Vooruit = foreward) or "A" (Achteruit = backward) on the panel FK or on the control desk. Stopping is done by pressing knob 0 which is situated between the knobs "V" and "A".

The velocity of the flow is controled by the knobs marked "S" (Sneller = faster) or "L" (Langzamer = slower) which control the reduction of the hydraulic variator. The extreme conditions of the variator are electrically blocked. When these conditions are reached, the respective signal lamps which were illuminated at the moment when the knob was pressed, are extinguished. The signal lamps above the knobs "V" and "A" are illuminated when the motor runs in the according direction.

9. Ward Leonard System.

In the cellar a "Ward Leonard" type converter is installed for controlled D.C. supply to auxiliary motors in use with the cavitation tunnel. It consists of a three phase A.C. motor (380 V) a Leonard generator and a field generator. A second, larger converter consisting of two units, likewise placed in the cellar supplies current to the large towing carriage.

The smaller installation can supply D.C. motors of up to 3 hp. The field generator can supply 10 A at 220 V tension. The converter is started by turning a $\curlywedge - \Delta$ switch on the right side of the middle FK panels. The $\curlywedge$ position of the switch is passed during the turning of the switch and cannot be maintained. The stand by condition of the converter is signaled on the right FK panel in the measuring room and on the control desk.

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The motor which has to be supplied is connected below the left hand side of the FK case. Two motors can be connected simultanuously but only separate use is possible.

The motors are controlled only at the control desk, on which are found a potentiometerknob for speed control, a switch marked "L" and "R" for choice of the direction of turning and a switch marked "I" and "II" for the choice of motor. Also on the control desk a current meter and a tachometer are placed. With the knob marked "1500" a separate range of a quarter of the maximum range can be applied on the tachometer dial.

The normal range is 6.000 r.p.m. with the use of a 3 phase transducer generator with a sensitivity of about 20 V at 1.000 r.p.m.

C. Drainage pump experimental tanks.

In the cellar an extra drainage pump is placed for use with the two experimental tanks.

Before the pump is started, the valve to the sewer has to be opened as well as the valve connecting the pump with the tank to be drained off. The pump is operated by pressing knobs on the right side of the FK 16 panel in the cellar. In the conduits to the tanks, electrodes are placed for automatically stopping of the pump when one of both tanks is empty.

Note:

When the pump refuses to start, the reason can be that one of the electrodes is dry. A short period of opening of both valves to the tanks will solve the problem.

D. Drainage of waste water.

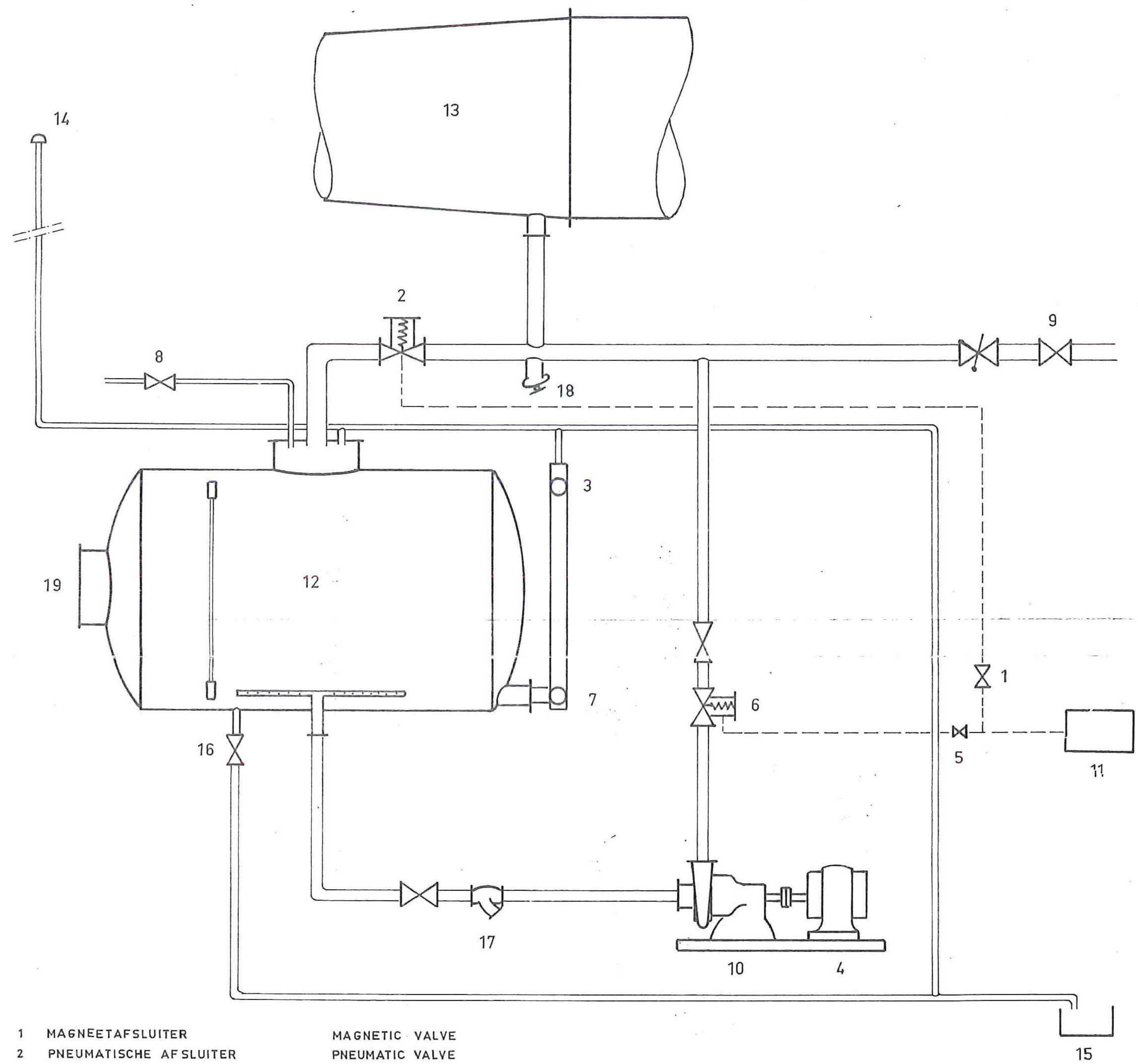
The waste water pumps in the cellar are operated automatically by electrodes dependant on the position of the switch on the nearby panel:

position 1: The right pump separately in use.
position 3: The left pump separately in use
position 2: (Normal) Both pumps alternatively in use.

In this last position the operation is as follows:
When the level in the pit reaches the first electrode, one of the pumps comes at work. Is the level below a certain hight, the pump stops. Does the water rise again to the prior level, the second pump will now do the work.

When one of the pumps has insufficient capacity to drain the incoming water, the level rises to a third hight where the resting pump is started to aid the other. At the same time a red signal is illuminated in the laboratory hall and a loud claxon is sounded. The noise can be cut out by pressing a knob on the aforementioned panel.

Delft, August 1962.

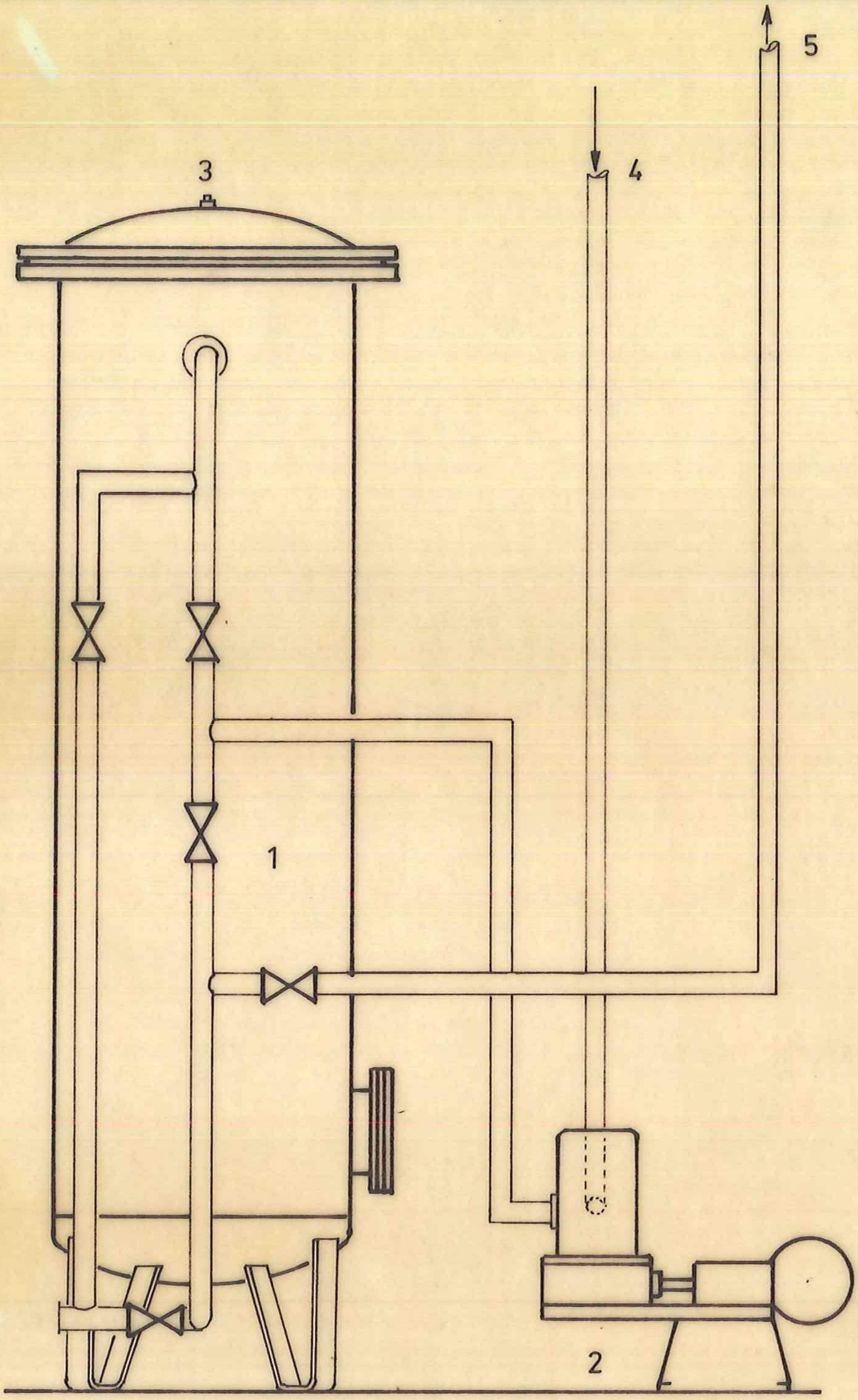


1	MAGNEETAFSLUITER	MAGNETIC VALVE
2	PNEUMATISCHE AFSLUITER	PNEUMATIC VALVE
3	MAX. VLOTTER	MAX. FLOAT
4	MOTOR	MOTOR
5	MAGNEET AFSLUITER	MAGNETIC VALVE
6	PNEUMATISCHE AFSLUITER	PNEUMATIC VALVE
7	MIN. VLOTTER	MIN. FLOAT
8	KRAAN	STOP_COCK
9	HANDAFSLUITER NAAR RIOOL	VALVE SEWER
10	CENTRIFUGAALPOMP	CENTRIFUGAL PUMP
11	LUCHTCOMPRESSOR	AIR COMPRESSOR
12	OPSLAGTANK	STORAGE TANK
13	CAVITATIE TUNNEL	CAVITATION TUNNEL
14	ONTLUCHTING	AIR VENTIEL
15	VUILWATERPUT	WELL
16	HANDAFSLUITER	DRAIN_COCK.
17	ZEEF	SIEVE
18	AANSLUITING WATERZUIVERING	CONNECTION FILTER FIG. 2
19	MANGAT	MANHOLE

SCHEMA WATEROPSLAG.

SCHEME WATER_SUPPLY

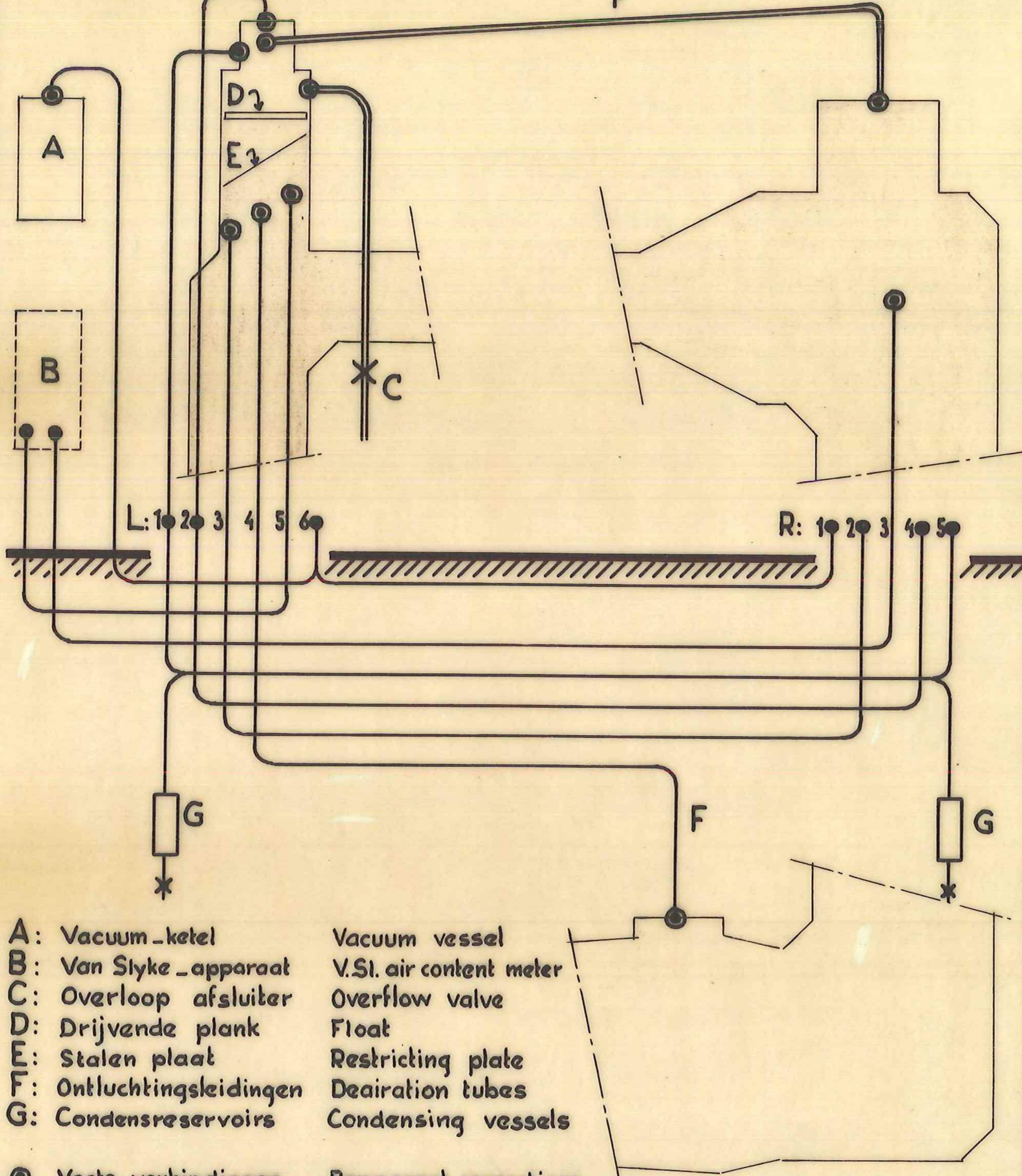
FIG. 1



1	FILTER	FILTER
2	POMP	PUMP
3	ONTLUCHTING	AIR VENTIEL
4	AANSLUITING CAV. TUNNEL	CONNECTION CAV. TUNNEL
5	- - -	- - -

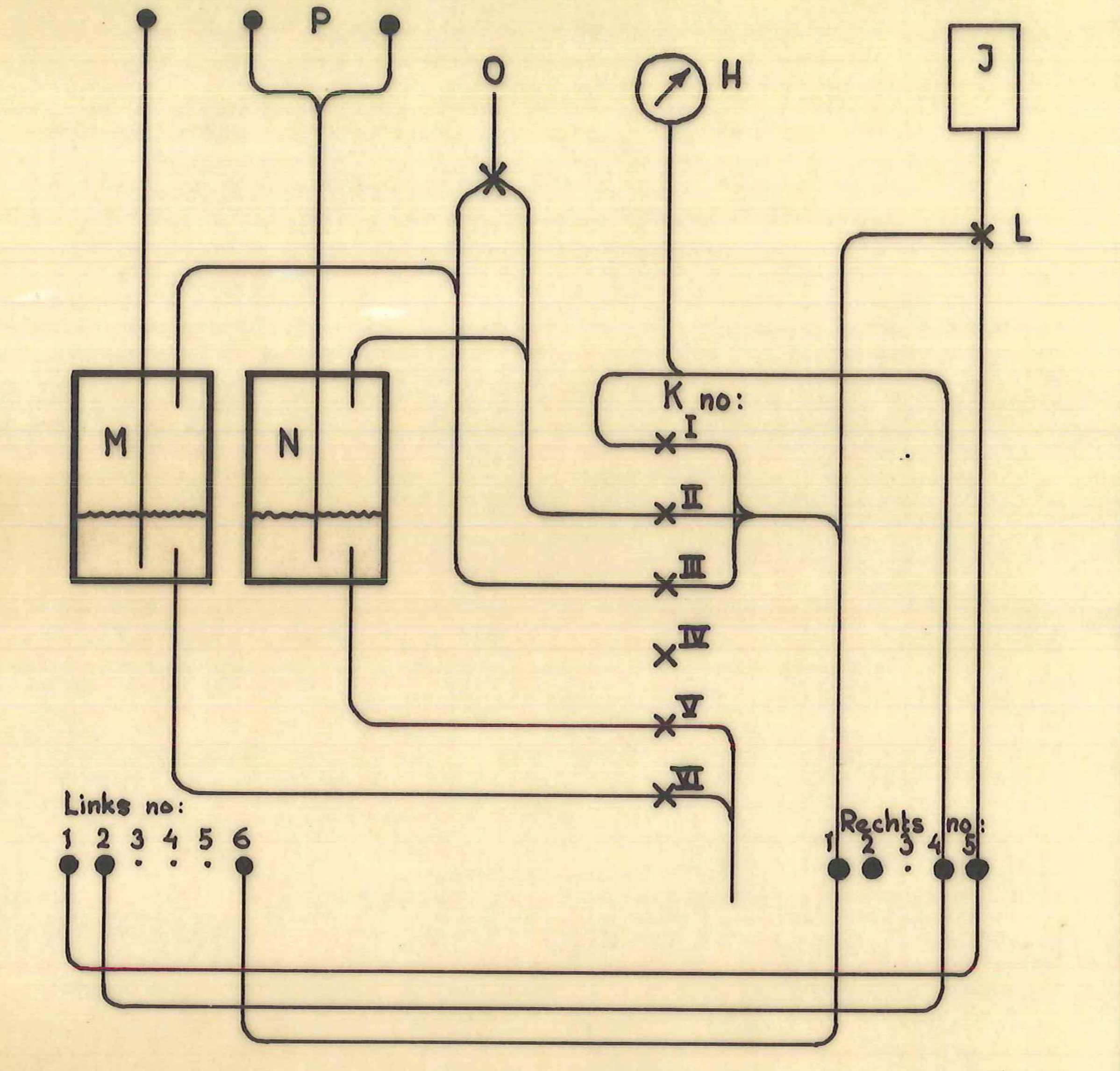
SCHEMA FILTER
SCHEME FILTER

FIG. 2



A:	Vacuum-ketel	Vacuum vessel
B:	Van Slyke-apparaat	V.Sl. air content meter
C:	Overloop afsluiter	Overflow valve
D:	Drijvende plank	Float
E:	Stalen plaat	Restricting plate
F:	Ontluchtingsleidingen	Deairation tubes
G:	Condensreservoirs	Condensing vessels
◉	Vaste verbindingen	Permanent connections
•	Aftakpunten	Connection taps

SCHEMA VASTE LEIDINGEN
SCHEME PERMANENT TUBES



H	Mech. manometer	Mech. manometer
J	Drukautomaat	Vacuum control transducer
K	Naaldafsluiters	Valves
L	Driewegkraan	3-way cock
M	Reserve zuigvat	Vacuum vessel
N	Zuigvat voor ontluchting meetleidingen	Vacuum vessel for deairation of manometer tubes
O	Driewegkraan	3-way cock
P	Aansluitpunten meetleidingen	Connection taps for manometer-tubes.

SCHEMA MANOMETERREK
SCHEME MANOMETERRACK