Use of steel in hydraulic structures, movable plants

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Use of Steel in Hydraulic Structures, Movable Plants.

Anwendung des Stahles im Wasserbau, bewegliche Anlagen.

Application de l'acier en construction hydraulique, installations mobiles.

Ministerialrat K. Burkowitz,
Reichs- und Preußisches Verkehrsministerium, Berlin.

The Material "Steel".

While in general I may refer to the contribution of Prof. Dr.-Ing. *Agatz*, I should like personally to say something with regard to the special section "movable plants".

Movable plants are more exposed to all external influences than the "fixed plants" are. The water, which often flows past them with considerable speed and force, the alternations between wet and dry state, cold and heat, and the adverse effects of external forces — these are all factors which in many cases, if not the majority, put a bigger strain on the material than is the case with fixed plants. In many cases the calculations made on a purely static basis are not sufficient to take account of dynamic forces, and a great deal of experience — much of it unsatisfactory — will be necessary before it is possible to evolve new methods of calculation.

As regards strength conditions, there are plenty of goods grades of steel (from ordinary Structural Steel 37, Steel 48 and Steel "Si" to Steel 52) available for meeting the various requirements; but it is not always the steel of higher-strength which is the better for the particular conditions involved, when corrosion, tendency to vibration, machinability, etc. have be allowed for as well. "Steel" is an excellent material for the moving parts of hydraulic plants, but its high elasticity, and the deformation capacity which this involves, call for special consideration when the parts are being designed and machined. Riveted joints in structural steel parts were only regarded as a makeshift in movable hydraulic structures, until the engineer had learnt how to do things better. Welding is now being adopted, enabling the material to be placed just where it is required, besides preventing the weakening of cross-sections by rivet-holes and the accumulation of materials at inaccessible places. Welding also meets the requirements of impermeability much better. It is only to be hoped that rolling mill practice will soon follow the requirements of welding technology, so as to avoid having to weld with rolled sections which were really designed for riveting. Fortunately a start is being made in this direction.

Of the many enemies of steel besides rust, we may merely mention the balanids in marine areas. Rusting is combated by painting (see Agatz's paper), but sufficient experience has not been gained in this connection to enable definite and generally applicable specifications to be given for the under-water painting of structural steel parts. It is true that certain "general rules" are followed, but these leave considerable latitude for further research and experience. This particular subject has been dealt with in greatest detail by Mr. *Wedler*,[1] Government Adviser.

The balanids penetrate the film of paint and expose the steel underneath to the destructive effects of sea-water. Even poisonpaints have been unsuccessful in getting the upper hand of these creatures. An effective means appears to have been discovered recently for combating the balanids. This is a cement-milk type of paint which forms a hard, vitreous ground-film on the iron Dunker & Co., Hamburg). It has been used for the Holtenau sliding lockgates of the Kaiser-Wilhelm Canal. Opinions differ at present as to the value or otherwise of a red-lead ground coating for steel structures in water. The paints which seem to have proved most satisfactory for under-water steel structures are those with a bituminous base, applied hot in a fairly thick coating.

Nature of the novable Plants.

The big majority of the movable steel structures or structural parts are used for barring or giving access to the water in definite channels; they are "seals" or "valves" such as are used in a smaller but similar form in engineering.

Throttle valves are there for the purpose of throttling the flow of water, and are often used as emergency stops in pipe-lines. But they can only be used in their limiting positions of "open" and "closed", because in all intermediate positions they result in unfavourable conditions of flow in the pipe. Even when wide open they constrict the cross-section of flow, and are so much exposed to the flow that they usually require special protection.

Sluice Valves, resembling ordinary stop valves, are constructed and used up to considerable dimensions. When open, they leave the cross-section of the pipe quite free, but they are very difficult to move under high and full water-pressure. When partly open, the flow conditions at the edges of the sluice-valve are extremely unfavourable, and there is a risk of cavitation.

Cylindrical Type Valves are frequently used and preferred. There are two usual types: (1) the simple form, consisting of long cylinders open at the top, which are raised vertically and seal with their bottom edge (a type frequently adopted on locks of the water-storage basins); (2) the closed form, recently developed by the Krupp-Gruson-Werk, in which the cylindrical sliding portion is drawn into a bell-shaped cowl, closed at the top and suspended from a traverse in the valve shaft (Fig. 1). The closed design prevents air being drawn in as well and causing trouble farther down the line (sluice at Fürstenberg-on-the-Oder).

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[1] Wedle: Unterwasseranstriche für Stahlbauteile im Wasserbau, besonders von Schleusen und Wehren. Bautechnik, No. 17 (1934), p. 232.

A typical cylindrical valve of unusual dimensions (made of cast steel) is that incorporated in the bottom outles of the Ottmachau dam (Fig. 2, taken from ZDVI., N° 31 (1935), p. 858), which was constructed by the Vereinigte Oberschlesische Hüttenwerke, Donnersmarckhütte, Hindenburg (Upper Silesia) to the designs of Government Adviser Mr. Chop of Breslau. These valves (six in all) have to carry off 500 m^3 of water per sec, at a head of 12.5 m. Special deflection of the water is said to considerably destroy the energy of the flowing water in the valve without fear of cavitation. Exhaustive model tests preceded the manufacture of these valves and have since been confirmed by practical performance. These valves are also successfully used for fine regu-

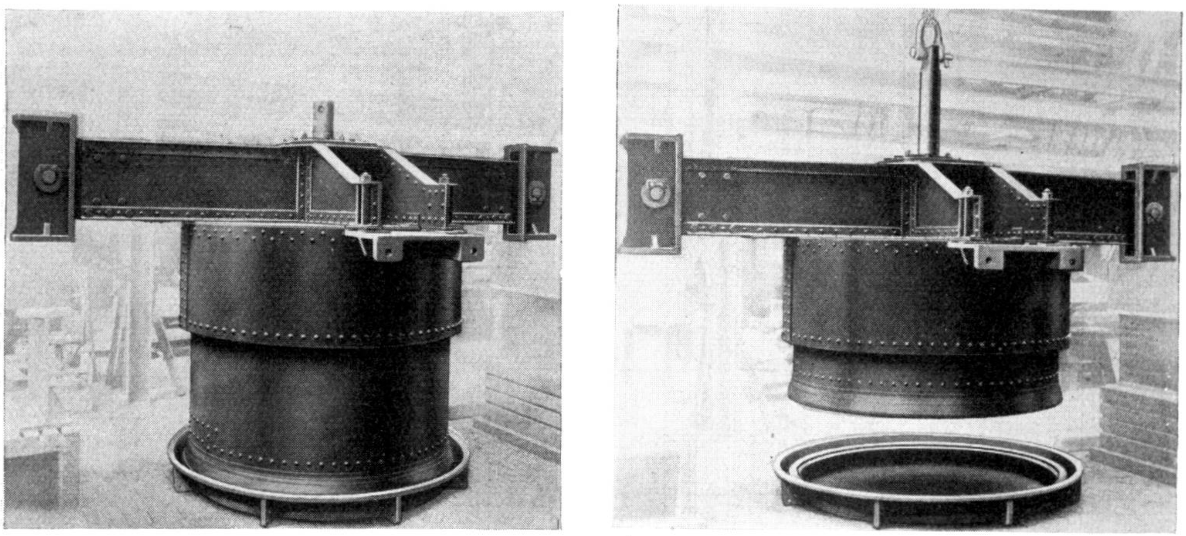
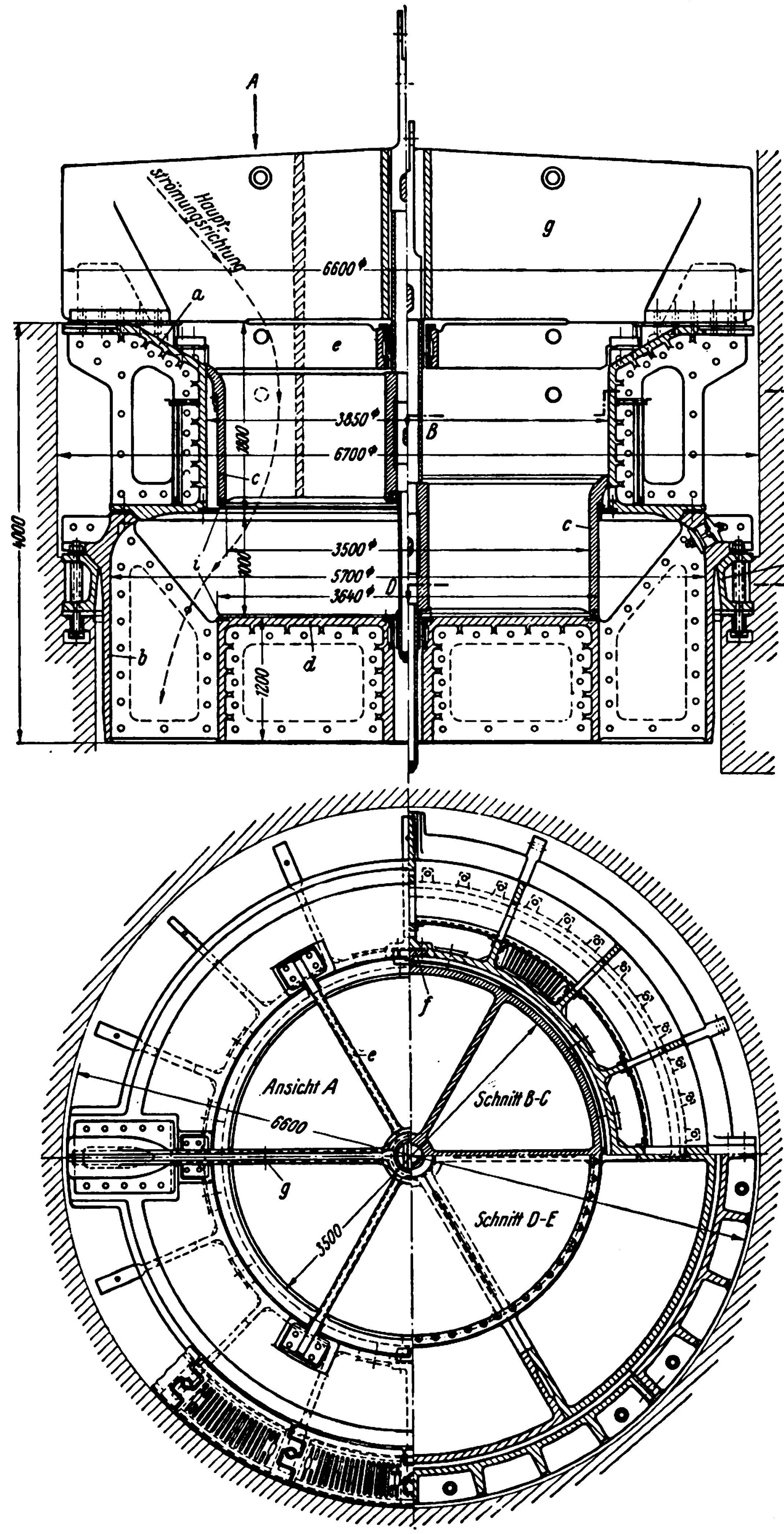


Fig. 1.
Closed type cylinder valve of Friedr. Krupp Grusonwerk A.-G., Magdeburg-Buckau, (patented).

lation in the intermediate positions between "open" and "shut". Fig. 3 gives en idea of the size of these valves, which the makers found it a very big problem to cast and machine.

Larner-Johnson Valves are called for where the valves have to be arranged horizontally instead of vertically. They are circular slide valves with a horizontal stem, and can be built to seal in both directions. At the same time, the pressure of water can be extensively utilised for releasing the moving portion of the valve, so that very little power is required for opening and closing the valve. The valve can even be made to close automatically against the pressure of the water. Two-way annular valves of the Maschinenfabrik Gebr. Ardelt (Eberswalde) have been fitted in the form of compensating valves beetween the two shaft locks of the twin-lock at Fürstenberg-on-the-Oder. The Krupp-Grusonwerke of Magdeburg manufacture bottom discharge valves of the Larner-Johnson type in which the head pressure itself is utilised for opening and closing the valve (Fig. 4, from ZDVI. N° 22 (1934)). Only the small needle valve *i*, requiring a sligth amount of power, need be operated to make the water-pressure in the chambers a, b, d available for opening or closing. Such valves have been fitted, inter alia, at the Sösetal Dam and at the Oder im the Harz, in the latter



a Inlet-funnel of the upper valve casing.
b Outlet in the lower valve casing.
c Valve cylinder.
d Valve floor (impact floor).
e Guides in star-arrangement.
f Guides for valve-body.
g Water divider.
h Seating ring for valve cylinder.
i Metal-packing with rubber gasket.

Fig. 2.
Bottom outlet-valve for the Storage Basin Ottmachau-Upper Silesia.
(Sectional elevation left half: Valve open, right half: Valve closed.)
Makers: Vereinigte Oberschlesische Hüttenwerke, Werk Donnersmarckhütte in Hindenburg/O.-S.

case for a maximum volume of 30 m³/sec. at a head of 55 m, with an inside diameter of 1.27 m.

Like the Larner-Johnson Valves, the Drum Sluice Valves can also be fitted into horizontal conduits. Fig. 5 shows their make-up and how they operate. When open, the slide valve completely frees the cross-section of the pipe, and adapts itself perfectly to the curvature of the pipe-wall. When closed, it forms a kind of mitre gate against the flow of the water, but can seal against both direction of flow. The end settings are satisfactory, but in the interme-

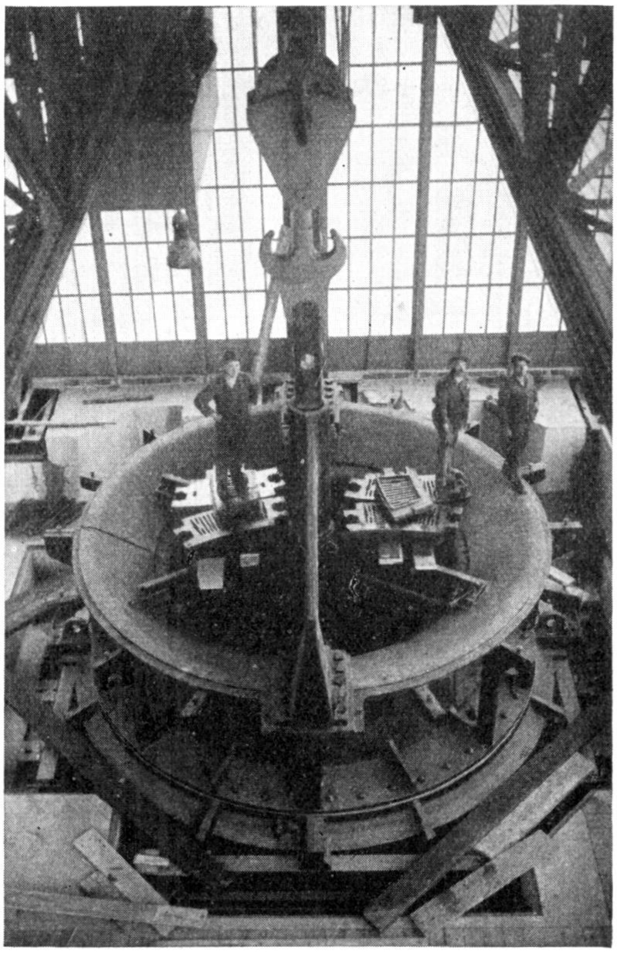


Fig. 3.
Cylinder valve as Fig. 2 during erection.

diate positions cavities form which may lead to heavy knocking effects by water (Fürstenberg/Oder Lock). It is therefore inadvisable to keep these valves in the intermediate positions for any length of time.

Sliding Sluice Valves are among the oldest of sealing devices on locks, dykes, weirs, etc. They are extremely simple and cheap, and also sufficiently tight, but they set up considerable resistance to motion when the dimensions are too large or the water-pressures too high. In the latter case, they are replaced by Roller Sluices. The arrangements for guiding and sealing must be separated, the former being taken care of by supporting wheels on tracks, and the latter by special arrangements. The sluice gate usually seals at the bottom and also at the top, when necessary — by abutment against a packing strip which may be of timber, or of machined steel or other metal. A slightly elastic packing (say, rubber, or springs) is generally used for the top, since hard surfaces in two planes cannot ensure a watertight joint in the long run. The

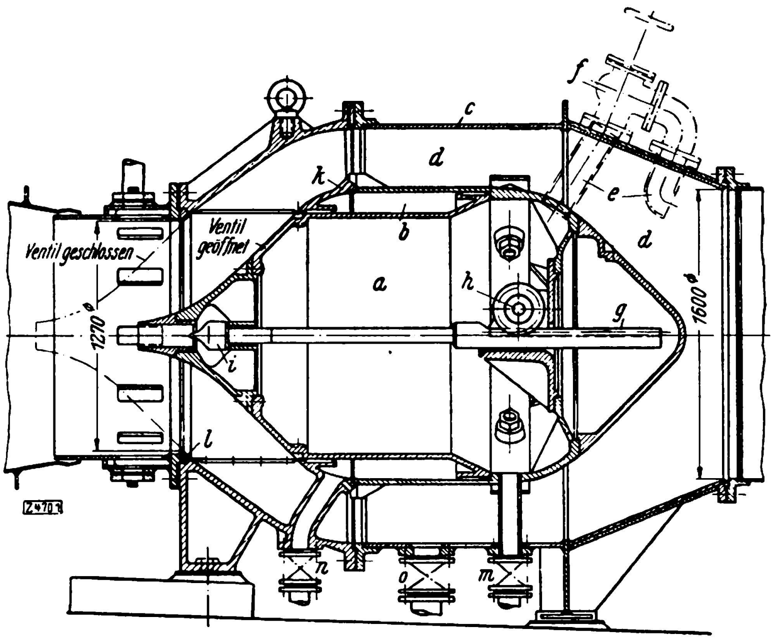
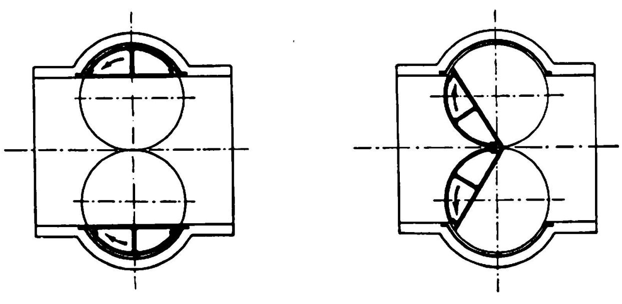


Fig. 4.

Bottom outlet valve Larner-Johnson system, type Krupp-Grusonwerk-Magdeburg.

side packing unsually consists of spring-strips, aided by the pressure of the water. It is best to make the side packings wedge-shaped in front, so that the packings can travel easily into their final positions. Tapered packings must be prevented from jamening or seizing by providing for a certain amount of



Valve open Valve closed

Fig. 5.

Drum-valve, general arrangement.

"give" in the packing strips. Rolling Wedge Sluice Gates are now being manufactured up to considerable dimensions. They have the big advantage of being very accessible, and if necessary can be lifted out bodily. A large Wedge Sluice Gate of the Krupp-Grusonwerk Company is shown in Fig. 6 (Fürstenberg-on-Oder Lock; down stream end 7.2 m² discharge section, head 15.8 m).

L o c k s provide the most frequent and natural incentive for the use of shutters of the most varied types. Originally, mitre leaf gates were probably used almost exclusively for sealing off lock-chambers. They can scarcely be surpassed for simplicity and reliability, and for this reason are still used up to very large dimensions. They almost lead the field for inland waterway locks. But they are only safe when movements of the crowns are excluded, and they become inconvenient when the resisting pressure becomes too high, or the heigt/width ratio of the leaves of the gate is too unfavourable. Generally speaking, mitre leaf lock gates should never be used in regions subject to mine subsidences (see Lift Gates). One inconvenience of the mitre leaf lock gates is that a separate drive is required for each leaf, thus involving mechanical equipment on either side. Drop gates avoid this drawback, for they can be operated from one side provided they are rigid when rotated and do not have to be moved against water pressures that are too high. Their weight can be sufficiently compensated for by the buoyancy of the water. Drop gates may therefore be satisfactorily instal-

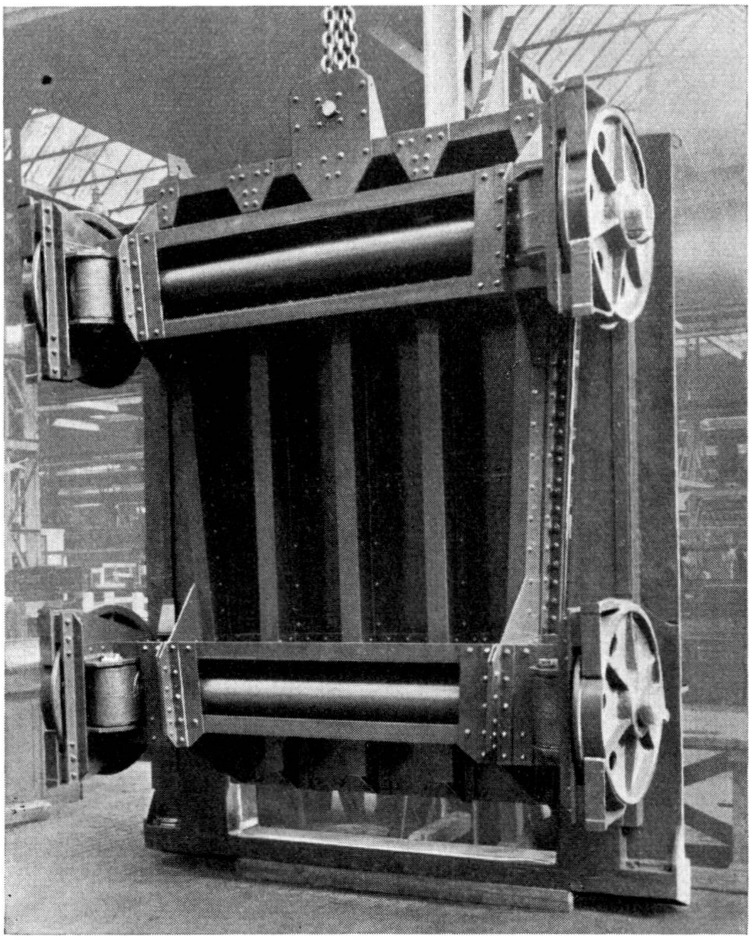


Fig. 6.

Twin sluice gate for Fürstenberg a. O. Down-stream head, tapered wedge sluice gate made by Krupp-Gruson Werk.

led in the upstream end of locks with elevated sills (see Fig. 7, Drop Gate of the Fürstenberg Lock, upstream end; in the background, a cylindrical valve). A remarkable feature of the illustration is that the lower bearings of the drop gate, which would otherwise be difficult of access, are supported against a spring thrust rod, so that the bearing can gape when foreign matter sticks in it. These bearings are also supported on vertical suspension ties, thus enabling the gate to be floated rigth up and the bearings inspected at the surface of the water.

In those regions of Germany subject to mine subsidences, Lift Gates are preferred to other types, as these are able to follow the pronounced displace-

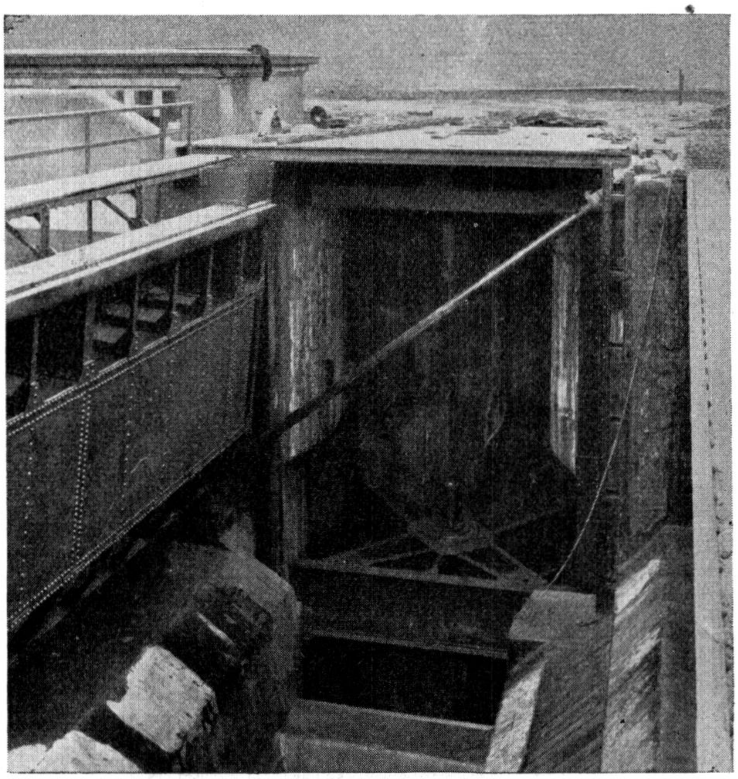


Fig. 7.
Twin shaft-sluice Fürstenberg a. O.
Up-stream head cylindrical bell-shaped valve made by Krupp-Grusonwerk.

ments of the abutments. The locks on the Weser-Datteln Canal are equipped in this way. Lift gates are also the type to use for the pumping and trough connections on ships' hoisting gear (Henrichenburg, Niederfinow), at the down stream end of shaft locks, and everywhere that sufficient height can be provided for raising the gates, and lifting stages do not cause inconvenience. The lift type of gate has the big advantage of accessibility, with the drawback of high cost; it is probably the most expensive of all lock gates. One of the newest lift gates for lock is shown in Fig. 8. The plant was constructed in 1934 for the Herbrum Lock of the Dortmund-Ems Canal.

In some respects, the lift gates are nothing more than a large roller sluice. The idea occured to engineers to utilise the gate itself as a sluice, at least from the moment when the gate has been partially released from the load of its headwater. The question then arose: "By-passes or not?"[2 3]

With the increase in the lengths of the chambers and the heads, engineers realised that no further progress could be achieved with the original arrangement of sluices in the lock gates, as the vessels in the lock would be too much disturbed when the volume of water necessary for locking them economically was thrown against them from the gate. By-passes were therefore devised, and were regarded as indispensible for long and deep locks, especially for towing locks, although the by-passes with their shutters and the piercing of the walls of the chambers were anything but simple and desirable. In regions subject to

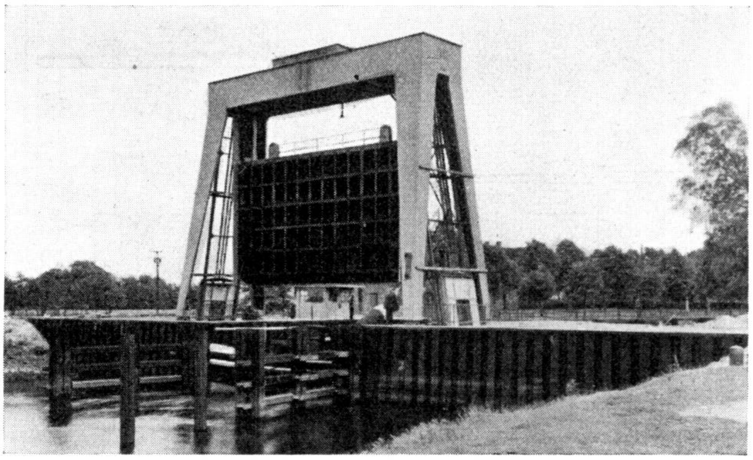


Fig. 8.
Sluice at Herbrum of the Dortmund-Ems-Canal,
Liftgate, with hinged sprocket-bar drive, built by M.A.N.

mine subsidences, in particular, the weakening of the head and chamber walls was very undesirable. Exhaustive model tests showed that by-passes can very well be dispensed with provided the water be guided and retarded properly.

It is true that the heavy lift gates cannot be raised against the weight of water, and the mitre-leaf gates less so. However, sluices are incorporated in the gates (reverting to a certain extent to the original design of an earlier age), and the water is filled or discharged through the gates. But care is taken to ensure that the rushing water is not directed against the ships, but is deflected several times so that it loses its force and cannot endanger the craft. The aim is to get, behind the gate, a drop in level whose highest point comes just behind the gate, so that ships lying in the lock-chamber only experience a moderate current always running in the same direction. Segment-shaped sluices are very suitable for fitting in lock-gates, as they are easy to move and provide a satisfactory outlet. Fig. 9 shows a nonbypassed shutter of this kind formed by a mitre-leaf gate with segmented sluice, and installed at the "Hirschhorn" Lock. The breakwater beam is heavily reinforced with iron, and illustrates one

[2] Regierungsbaurat Dr. Ing. *Burkhardt* about model tests with locks without circulation in "Die Bautechnik" (1927), No. 3.

[3] The same just there, No. 31, about observations and experiences at the Double lock (without circulation) Ladenburg of the Neckar Canal.

advantageous use of steel in hydraulic construction work. It seems as if the non-bypassed type of lock will be the rule in future, since previous operating results have proved satisfactory.

For sea locks of very large dimensions, especially those located in the tidal region, where the gate must be able to shut off the water in both directions, mitre-leaf gates are often unsuitable, being replaced by Sliding Gates, which are very little effected by waves. In large modern sliding gates, the front end runs on a bottom carriage, from which it may be lifted, and the rear end

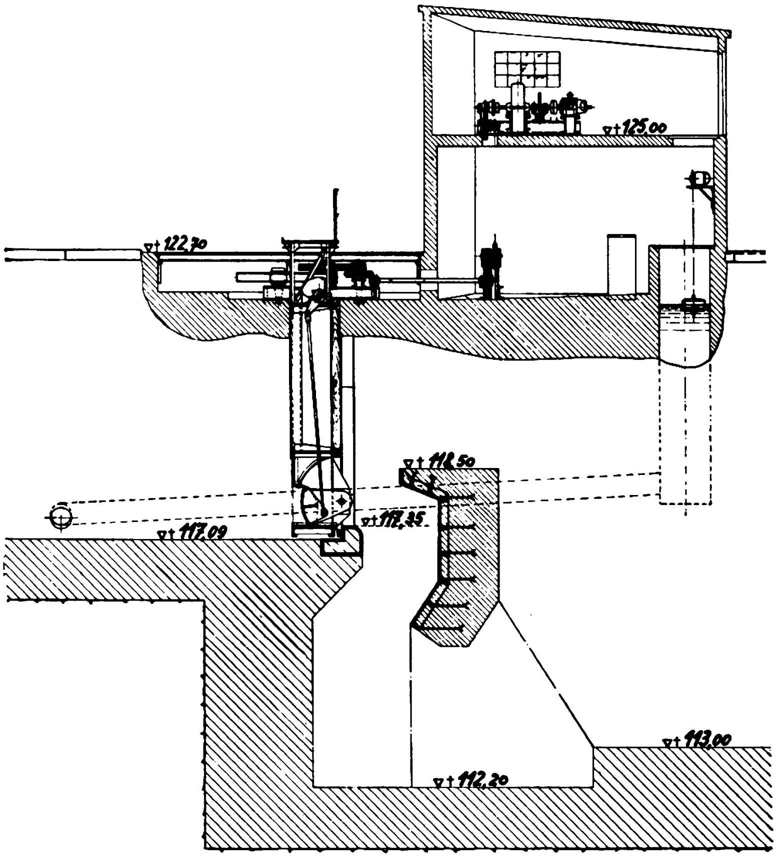


Fig. 9.

Sluice at Hirschhorn of the Neckar Canal, up-stream head, mitre-gate with segmental sluices. No by-passes. Energy of water destroyed by braking chamber.

on a top carriage (Fig. 10, showing the sliding gate at Bremerhaven; chamber 372 m long and 50 m wide). Among the sliding gates should be included the Floating Caisson Gates, which are used specially for closing off dry docks. They have to be balanced by floating caissons so that they can be floated into the gate recess and lowered in this on to the sill. They form the transition from hydraulic construction work to shipbuilding.

An attempt is being made to fill a lock-chamber without bypasses, probably by overflow over a gate which can be lowered [upper gate of the Sersno (Upper Silesia) lock], now under construction. For this purpose, the segment gate acting against the head water is the most suitable type, as it is raised from its sill by the pressure of the water. To obviate unnecessary slip under load, the raising and lowering movements will be separate from the pressure movement closing, and such closing pressure will only be applied when the gate is stationary. The overfall conditions have been satisfactorily settled by preliminary tests, but actual experience must show whether this type of gate is efficient in other respects.

What lock-gates are on a small scale, Safety Gates are on a big scale. Their function is to prevent higher reaches of the canal wasting water if a dam bursts, etc., and they also belong in the vicinity of the upper retaining shutters of ships' hoists. Very wide gates of the lift type are usually employed, as they must block or free the entire cross-sectional area of the canal. They must be capable of being lowered at any time without much delay, often by remote

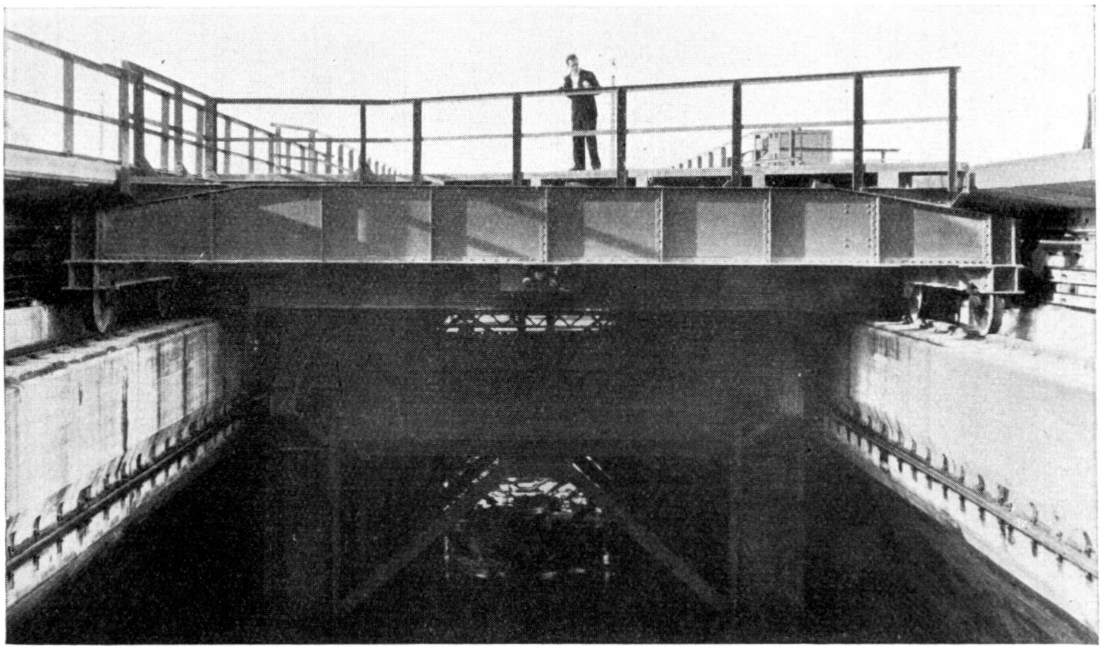


Fig. 10.
Sliding gate at Bremerhaven, upper carriage, built by M.A.N.

release operated from a point of observation, whereas more time can be allowed for raising them again. One of the newest safety lift gates is the one constructed for Duisburg-Meiderich for 11.5 m lift and a lifting force of 100 tons (Fig. 11).

Weirs, so far as they are movable, must not only keep up the water-level, but also control it as desired. The old-fashioned needle weir, which ist still used, only partially fulfils this requirement, and with a certain amount of risk for the attendant. The needle supports and weir pedestals are nevetheless remarkable as exemplifying the use of steel in hydraulic construction works of an earlier period. The more modern weirs are made almost throughout of steel, except for the masonry or concrete of the body.

Even Sluice Weirs, which initially were often made of timber on an iron framing, are tending more and more to become purely steel structures, with the result that the spans attainable have increased to 40 m, and the heights of damming to 12.5 m. For smaller weirs and low heigths of damming, it was formerly the practice to regulate the flow of water by raising the lower edge of the sluice-gate; but it was soon found preferable to operate the fine regulation by lowering the top edge, i. e., making the sluice in at least two parts, and dropping a lower top-portion down behind (in the direction of the water flow) a stiffened plate wall of the lower leaf. The M.A.N. Company have developed very suitable types with a common track for the lower and upper sluices. In cases of need, the upper sluice can be made so high that fairly large volumes of water can be carried off above the weir instead of below it. By placing on the lower sluice a folding flap in place of a top portion, the Drop Gates

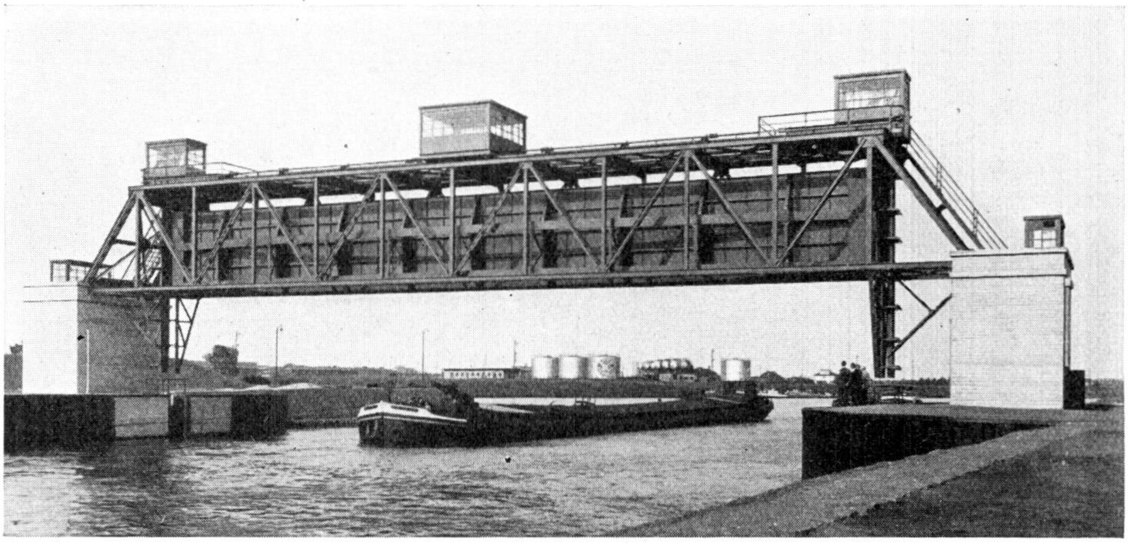


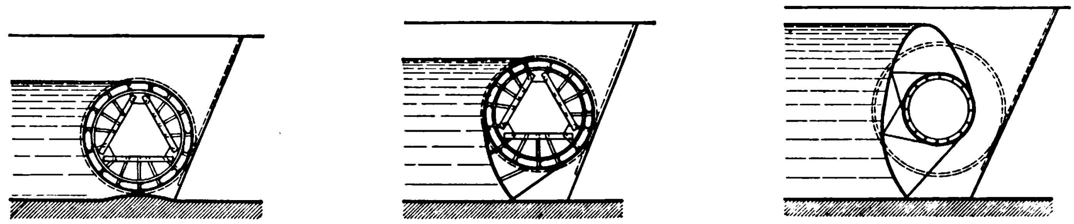
Fig. 11.
Safety lift-gate at Duisburg-Meiderich, built 1935 by M.A.N.

resulted, in which one operating gear usually folds back the flap first and then raises the entire sluice.

Drop Weirs have been built on similar lines to the drop gates for locks. They are lowered by the pressure of the water and erected against it. To enable these to be operated with power from one side only, the flap had to have a fixed (non-turning) axis and be made non-rotating itself. This led to the development of the fish-bellied type of flap, an example of which is found at the discharge weir on the equalising reservoir of the Bleiloch barrage.

A feature of the drop weir is that the flap must be rigidly pivoted to the sill of the weir, and can only operate by overflow. The flap has to be moved over completely when it is desired to release precipitates which have accumulated in front of it. For this reason, the drop weir pure and simple will only be suitable in specific cases.

The Roller Weir has a much wider scope and has been extensively adopted. It is very strong and insensitive, can bridge wide spans, and, being rigid, can be operated with a single drive, whereas sluice-gate weirs must always be operated from both sides. Ice and rubble do not affect it, and the overflow conditions are satisfactory without additional aid. The M.A.N. Co., in particular, have spent more than 30 years developing this type of weir. When conditions are suitable, the diameter of the roller is made the same as the height dammed, and the water allowed to flow over the roller. For small spans but greater heigths of damming, the diameter of the roller would be excessive. In this case a separate apron is itted in front of the suitably dimensioned roller, or the roller extended downwards by a kind of bill (Fig. 12, taken from an M.A.N. prospectus). The bill or apron comes up against the roller free from deposits of any kind when the roller rolls down. The rollers are raised on the track (having a marked upward incline) usually with Gall chains (sprockets), racks on the guide rails ensuring that the roller runs up evenly at both ends. It is a remarkable fact that, of all the types of weirs, the roller is probably least affected by ice. Hitherto, roller weirs in Germany have not had to be



Roller weir of cylindrical section for relatively small depth of water in comparison to the length of the roller.

Roller weir with beak-shaped attachment for a deeper depth of water in relation to the length of the roller.

Roller weir with articulated damming shield for deep water compared with the length of the roller.

Fig. 12.

Three basic forms of roller-weirs of the M.A.N.

heated to prevent their freezing up. This has only been necessary in northern countries.

Like sluice weirs, roller weirs can also be provided with flaps (fish bellied form) when special conditions, say, getting ice away over the roller, make it necessary. These flaps are usually operated at the same time as the roller by the winding gear for the latter. Larger weirs are now usually divided up so that one opening with a flap roller (or sometimes a drop roller) is placed between two openings with standard rollers.

Steel is also used in movable plants of hydraulic construction works such as dredgers, scouring apparatus, tugs, barges, etc., but it is beyond the scope of this paper to discuss these further. Nor will further mention be made of pipelines for scouring plants, siphon discharge plants, or hydro-electric plants, as these are no longer counted as movable hydraulic construction works.

On the other hand, it might be well to deal briefly with operating gear for hydraulic construction works. Every mobile engineering job requires gear to operate it — to make it move in the direction desired and overcome all obstacles. Man power is usually insufficient to perform the lifting or shifting operations required. In the big majority of cases electricity can and must be employed, as it is now procurable nearly everywhere. As to whether it is direct or alternating current does not matter much for the present purpose. Only where large and heavy masses have to be reliably controlled will direct current

Ward-Leonard controlled circuits be preferable. Our large electrical firms have also developed satisfactory methods for enabling drives to be operated electrically in the same direction from different points, where there are difficulties in carrying a mechanical shaft through for the same purpose.

The operating gears consist practically throughout of "steel", including, of course, cast steel and, cast iron. All the main supporting parts like roller steel. ropes, chains, etc. are "steel", and therefore come into the category of steel parts for hydraulic construction works. The "link racks" developed by the M.A.N. Co. constitute a remarkable component of modern times, since they combine the advantages of Gall chains with those of rigid racks. They stand up equally well to tensile and compressive stresses, and have the added advantage of ensuring frictionless guiding at the driving pinion. They can also be successfully used for the largest, heavy-duty operating gears, such as those on the sliding gates at Bremerhaven.

Special Phenomena.

The high strength of steel combined with its high elasticity makes steel structures into units capable of vibrating, and each units has its own individual frequency. If regularly occurring impulses initiative vibrations in such structures, they will vibrate, and these vibrations may be dangerous when the inciting impulses keep step with the individual frequency of the structure (resonance). These vibrations may attain such dimensions that they eventually lead to fatigue fractures. If the vibrating units are made up of parts of different types, each capable of vibrating at different frequencies, stresses may occur at the connecting members (bolts, rivets, straps, etc.) which many times exceed the figures found by static tests. The parts particularly endangered are connections which have to be capable of standing up to considerable work of extension under vibrational deformation, but are unable to do so. Cases have been known where long and thin bolts have held up, whereas short and thick ones have broken in a short time.

Large-span sluices on weirs for instance, are prone to such vibrations. They are put under tension by the pressure of the water and set in vibration by its flow, pretty much the same as a violin string is vibrated when the bow is drawn across it. Dangerous vibrations of this kind have been observed at the weirs at Oldau and Marklendorf. In the overflow weir, the flaps, and in the underflow weir the entire body of the weir started to vibrate seriously, and the vibrations were always most pronounced for definite heigths of overflow and gap-openings. The weirs mentioned, with sluices of 15 m wide and 3.70 m high, vibrated at between 10 and 25 cm opening of gap, but most pronouncedly at 15 cm (above 25 cm, everything was quiet again!). Rivets were sheared, and cracks occurred in the main girders. Fine measurements showed that the damming wall vibrated at a different rate to the lattice supporting structure on the downstream side, and this must have set up considerable shearing stresses. The vibrations and their attendant dangers were gradually eliminated by making the lower dam beam of special shape (varying the section every metre). The effect of this was to disarrange the jets — previously uniform and closed — of the water rushing through the gap, and to deprive them of the possibility of initiating a particular type of vibration in the body of the weir. Model tests for further elucidating the problem of vibrations at weirs are in hand. This should open up a new and promising field of research.

Vibrations may, under certain circumstances, also be set up in valves, pipelines and the like and endanger the material. It would be a good thing if experience in this connection could be interchanged between the various contries.

Many parts of movable structures are sensitive to frost in a high degree. Sluice

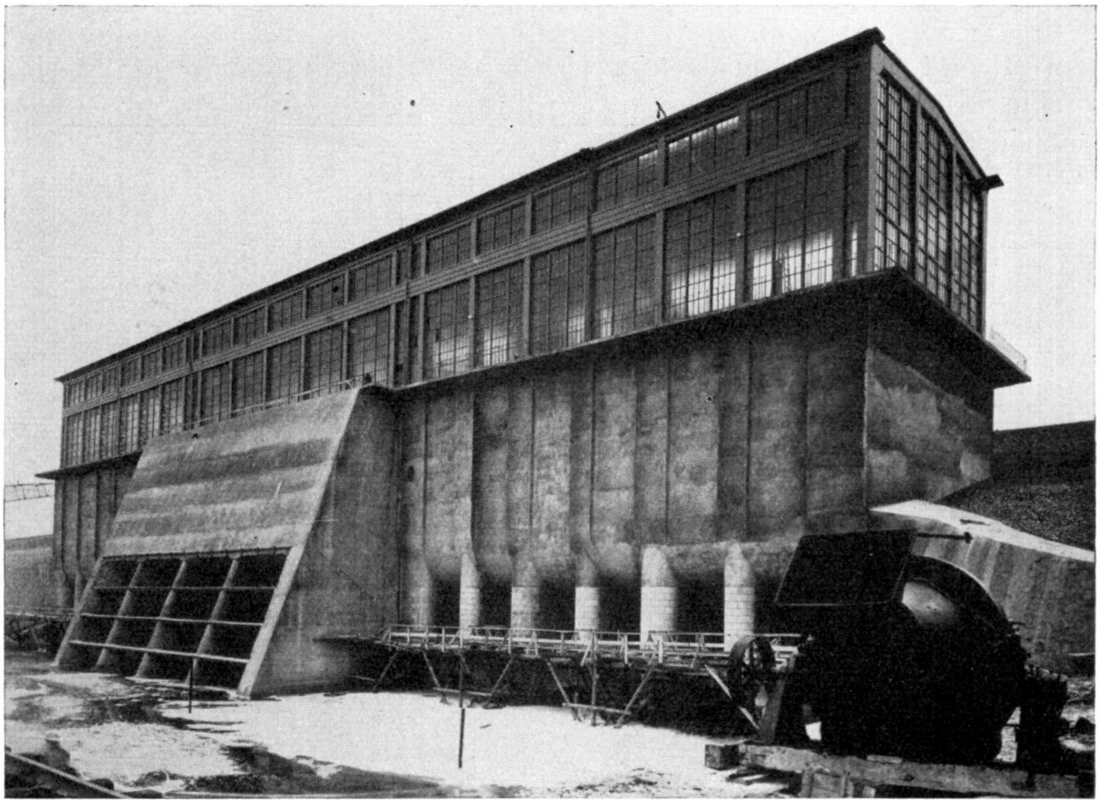


Fig. 13.
The steel-framed hall over the bottom outlet of the hydro-electric plant in the barrage of Ottmachau.

weirs may freeze up, lift gates become immovable before shipping has to lie up for the winter. One effectual but expensive way of combating this trouble would be to heat the sensitive parts by electricity (theoretically, 1 kilowatt-hour of energy yields only 860 calories!), following the practice adopted at the Weser Weir at Döverden or the ship's elevator at Niederfinow.

Other brief References.

Among the "movable" structures in water construction works should be included the ships elevators, of which the Henrichenburg and the Niederfinow plants are already working in Germany; they are probably the largest steel constructional works in hydraulic engineering in Germany, but they will not be dealt with here, as the ships' lifting plant at Niederfinow is discussed in a separate paper.

The Operating station above the bottom outlet and power plant at the Ottmachau reservoir dam is worthy of mention. Here a steel frame building has been erected and glazed over a large area (Fig. 13).

Brief mention only need be made of the fact that Pumping Stations and Power Plants use steel extensively in their construction, but they cannot be included among the "movable" structures of hydraulic engineering.

Summary.

An attempt has been made to give a brief review of the use of "steel" in movable hydraulic construction works, illustrated by examples of more recent plants in Germany.