both plants the speed rings are securely anchored to the reinforcing in the concrete forming the scroll cases and substructures. The higher turbine settings of the francis units above tailwater level kept scroll-case pressures low enough to permit forming the water passages and scroll cases directly in the concrete. Studies indicated the lower setting required for propeller turbines would have increased scroll-case pressure to where steel-plate penstocks and scroll cases would be required with their added cost. For these reasons, francis turbines with concrete scroll cases and water passages gave the most economical design.

Scroll-case pressures at Des Joachims made it desirable to use steel-plate scroll cases, triple-riveted to cast-steel speed rings. Circumferential joint between plates of the casings are field-welded, and longitudinal joints are shop-welded or field-riveted. Scroll cases are designed for 165-ft head, which includes an allowance for pressure rise. Penstocks are steel plate, 22 ft in diameter with welded longitudinal seams and riveted circumferential joints.

Turbine Runners. At all three plants, turbine runners are cast steel, double heat-treated to insure proper grain refinement throughout. Shafts are forged to meet special requirements as to reduction in forging and heat treatment. Exposed parts of each shaft are machined and polished to a finish of about 63 microinches. The guide bearing journals are machined and polished to a finish of 16 microinches or less.

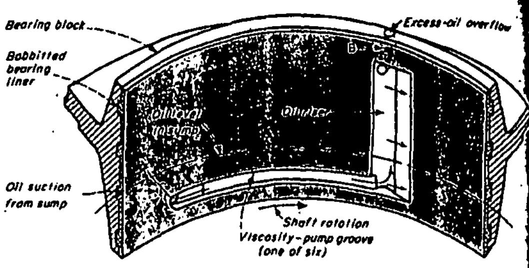
Turbine Bearings. There has been a recent trend toward oil-lubricated babbitt bearings for hydraulic turbines. Earlier turbines were generally installed in open flumes and the bearings were of necessity water lubricated. Lignum-vitae blocks, generally used, became standard equipment even on modern vertical-shaft units with reinforced-concrete or steel-plate spiral scroll cases with a head cover. Turbine bearing is close to the head cover and might be flooded if water pressure develops above crown of runner. Water-lubricated bearings made it unnecessary to worry about water getting into the oil.

As turbine and generator sizes increased it became difficult to keep lignum-vitae bearings adjusted to insure turbine and generator parts running true. Therefore it was desirable to use oil-lubricated bearings that could be adjusted to close tolerances. Sealing arrangements to prevent water leaking into these bearings have been developed so oil-lubricated guide bearings are today accepted as a necessary part of hydraulic turbine equipment.

Oil Lubrication. It is interesting to see how this trend toward oil-lubricated guide bearing has taken place on hydraulic turbines installed by the Hydro-Electric Power Commission of Ontario. During the 35 years before 1948 the Commission built 18 hydroelectric plants with 55 vertical shaft units of about 1,300,000-hp total capacity. Only two of these had babbitt bearings and they were installed about 25 years ago. All other turbines, put into operation, have water-lubricated lignum-vitae bearings.

Since that time 34 vertical-shaft units have been installed, including La Cave, totaling about 1,200,000 hp in seven plants. Of these only six units of 144,000-hp total capacity have water-lubricated lignum-vitae bearings. The other 28 have oil-lubricated babbitt bearings.

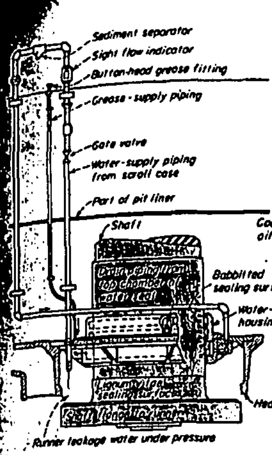
Guide-Bearing Designs. These turbine guide bearings are precision-bored, babbitt-lined, oil-lubricated, but two different types are used. Des Joachims design is similar to that at Chenaux, and on units No. 5 to 8 at La Cave. For La Cave units No. 1 to 4, Fig. 1 shows the general arrangement of the guide bearings and oil pumps.



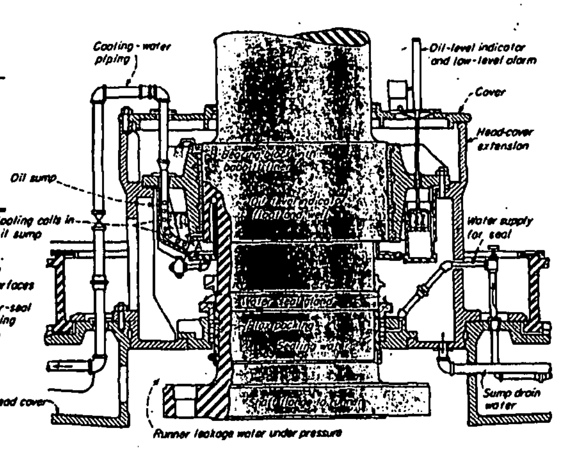
5 Segment of turbine's guide bearing shows viscosity-oil pump, oil riser and overflow pipe at Des Joachims, Chenaux, and on units No. 5 to 8 at La Cave

Principal Features, Dimensions, Weights of Turbines, Generators Installed at La Cave, Des Joachims and Chenaux

	La Cave Units 1 to 4	La Cave Units 5 to 8	Des Joachims 8 Units	Chenaux 8 Units
Turbine Features				
Manufacturer	Canadian Allis-Chalmers	John Inglis	Dominion Engineering	Dominion Engineering
Type	Francis	Francis	Francis	Fixed-blade propeller
Design head, ft	77	77	130	44
Capacity, hp	33,000	33,000	62,000	21,000
Speed, rpm	94.7	94.7	105.9	94.7
Specific speed, Ns	75	75	60	137
Rated discharge, cfs	4500	4500	5000	5000
Runner discharge dia, ft	14.6	16.25	14.5	17.1
Guide-vane circle dia, ft	19.3	18.5	16.3	20.3
Guide-vane height, ft	5.1	4.75	4.0	7.3
Runner vanes, number	17	13	17 & 15	6
Guide vanes, number	20	28	20	20
Stay vanes, number	10	14	10	16
Shaft diameter, in	30	30	35	25
Water thrust on runner, lb	300,000	330,000	570,000	583,000
Weight rotating parts, lb	133,000	143,000	160,000	93,000
Weight of turbine equipment, one unit, lb	570,000	550,000	815,000	635,000
Scroll case	Concrete	Concrete	Plate steel	Concrete
Generator Features				
Manufacturer	Canadian Westinghouse	Canadian Westinghouse	Canadian Westinghouse	Canadian General Electric
Capacity, kva	27,000	27,000	50,000	17,000
Power factor	0.95	0.95	0.90	[illegible]
Voltage, kv	13.8	13.8	13.8	13.8
Rotor diameter, in	319.5	319.3	316.9	[illegible]
Air-casing, inches square	433	432	432	[illegible]
Air-casing, height, in	110	110	139	[illegible]
Rotor weight, lb	370,000	370,000	550,000	[illegible]
Generator weight, lb	803,000	802,000	1,100,000	625,000
Machine total weight, lb	1,373,000	1,352,000	1,915,000	1,260,000



6 Turbine shafts, La Cave units 1-4 have babbitted and lignum-vitae sealing surfaces combined with annular grooves



7 Des Joachims turbines guide-bearing-and-shaft water seal uses flax packing. At Chenaux, carbon rings act as seals

An annular oil sump below the bearing surrounds the turbine shaft. A specially designed oil slinger connects to the shaft with a shoe-type viscosity-oil pump rubbing against the slinger. This pump is mounted in the oil sump so it is always below minimum oil level. Oil discharges from the pump to a small reservoir above the bearing. Leaving this reservoir, oil goes to an annular distributing well formed in the top of bearing block.

Oil, flowing by gravity down through the bearing, is carried to all parts of it by a network of vertical and horizontal grooves. Fig. 2 and 3 show details of the oil slinger and viscosity pump, while Fig. 4 gives the oil grooves in the guide bearing. Oil, discharging from the bottom end of the bearing, passes down over the oil slinger and goes to the sump. An automatic motor-driven rotary pump supplies oil to the bearing when starting the unit, or as standby should the viscosity pump fail.

Other Bearing Designs. Units No. 5 to 8 at La Cave and all units in Chenaux and Des Joachims have different guide-bearing arrangements. Machined horizontally around the bearing below minimum oil level in the sump, a series of six special grooves acting as viscosity pumps supply oil to the Des Joachims guide bearings, Fig. 5 and 7. Oil enters the viscosity pump grooves at the deep end by holes *A* drilled through the bearing block. Each pump groove leads to a specially shaped vertical one that acts as a riser to distribute oil to the bearing surface. Excess oil discharges to top of bearing block through a hole *B* in top of each riser and returns to the sump.

Cooling coils in the sumps keep oil viscosity at a correct value and prevent overheating. On Units No. 5 to 8 at La Cave, bearing blocks are cored to form internal coolant passages, so cooling coils are not required in the sump. *Water circulates under pressure through* the coils and passages. Units No. 1 to 4 at La Cave do not have a cooling coil in the oil sumps.

Water Seals. Below the guide bearing of each unit a water seal or stuffing box prevents oil loss to the tailrace or mixing of leakage water from above the runner with oil in the bearing. The seal has annual grooves that drain away any water that may rise through the clearances between the turbine shaft and the grease- or water-lubricated sealing surfaces. At La Cave, units No. 1 to 4 have babbitted and lignum-vitae sealing surfaces, Fig. 1 and 6. Sealing surfaces at Des Joachims are flax packing, Fig. 7. Carbon rings are used for sealing at Chenaux and for unit No. 5 to 8 at La Cave.

All turbine bearings other than that on the main shaft have high-pressure grease fittings, lubricated from a portable grease compressor.

Generators. At Des Joachims and Chenaux, rated generator capacity conforms to turbine capacity at rated head. La Cave operates at a head about 6% above the normal on which turbine rating is based during the season of large water storage. For this reason generator ratings were based on turbine output at maximum head.

At all three plants the generators are totally enclosed, ventilating air being circulated through air- to water-heat exchangers, mounted within the enclosing housing. The housings are square and *have dampers so* part of the air may be circulated in the powerhouse for winter heating. Totally enclosed units were selected to (1) reduce cost of cleaning machine windings (2) reduce noise (3) have a cooler powerhouse in summer.

At Chenaux each generator sets in the substructure so only part of the bridge upper bracket and the exciter extends above the main floor. Stator is in a square recess in the foundation with cover plates at the main floor to complete the enclosure. Des Joachims and La Cave generator casings are above the main floor. Because of the francis-turbine settings and deeper stator frames, the limit to which the latter could be depressed would still have left a large part of the air casing exposed.

Sprinkler rings are installed in all

(*Continued on page 204*)