Spray Vessel Fluid Flows.

Artemis-Danfoss digital hydraulic machines, originally designed for power conversion in wave energy, have computer-controlled poppet valves on each chamber allowing them to change from pumping to idling to motoring every shaft rotation. They provide the key mechanism to convert the motion of a variable-pitch hydrofoil vessel into sub-micron spay for climate control.

At point A-14 in the attached drawing, the force input from a hydrofoil is levered up to drive a crosslink connected to the piston crown side of one ram at point F 16 and the rod side of the of the other ram at point F-15. Alternating pressures are set by the square of vessel velocity and the variable angle of incidence at the hydrofoils. Flows are rectified with a bridge of four non-return valves to a single pipe at E-13. The wave form will be a softened trapezium with some irregularity. There is pressure relief valve at point G-13 to remove hopefully infrequent high peaks above 390 bar.

Conventional fast hydraulic machines use an axial configuration with only a single oil service. Radial operation allows multiple banks with multiple oil services to share a common shaft. A multi-bank digital hydraulic machine with five services has a shaft running from D-12 to D-8. It has a direct current motor/generator at one end and a 3-phase synchronous machine at the other. Two banks of the machine at D-11 are driven by alternating flows from the hydraulic rams. A third bank at D-10 feeds energy at pressure up to 390 bar to a free-piston pressure accumulator at point F-11. There are backup nitrogen bottles at point H-11.

Two banks at D-9 take it in turns to feed alternating pulses at exactly 350 bar to each end of a free-piston pressure-exchanger running from L-16 to L-6 with energy smoothed by the free-piston accumulator but sometimes also short pulses of electrical energy from a graphene super capacitor when needed.

The free-piston pressure-exchanger delivers alternating pulses of oil at exactly 80 bar to two oil-to-water pressure exchangers by squeezing rubber tubes at O-13 and O-9. The deflection of the rubber is controlled by sets of three rods to give strains low enough for infinite fatigue life. The 80-bar pressure is set by the number of wafers allow to release spray and the fraction of pumping events enabled at the banks at D-9.

The flow rate of cold, plankton-rich sea water from inlets mounted on keels below the hydrofoils is controlled by frequency adjustment of the electrical drive frequency to Grundfos down-hole pumps in each hydrofoil at B-1 and D-3. The losses in high-pressure oil hydraulic machines are dominated by leakage and shear which are controlled in opposite directions by viscosity which is set by fluid temperature. Exact control of oil temperature is desirable despite a range of sea water temperatures from -2 C to +35C. The oil temperature must be controlled to give the optimum viscosity at present believed to be at a temperature 35 C.

Cold inlet water goes through a heat exchanger F-4 along with a controlled rate of oil from a hot tank at B-10 and I-2, to produce oil at the chosen ‘nice temperature’ in tanks at points B-8, H-16 and B -9.

Some sea water can sometimes contain 10 billion organisms in one litre. There will be many large enough to clog nozzles in the spray wafers. The first stage of sterilization is at G-6 where the water goes past a piezo-electric generator as used in ultrasonic cleaners which can give negative pressure spikes down to –7 bar at 40 KHz.

The second sterilization stage is provided by sucking the flow up a pipe mounted on the mast of a Flettner rotor with a suction pressure depending on the vapour-pressure of water at the working temperature. This will vacuum-strip most of the carbon dioxide needed by phytoplankton and oxygen needed by zooplankton and corrosion. Pressure is restored by the 10-metre drop down the mast.

The third sterilization stage at K-4 is with chlorine produced by electrolysis. A concentration of four parts per million will be double that recommended for municipal water supplies.

The fourth stage of sterilization at M-7 is by passage though a bank of 50 mm quartz tubes covered with light-emitting diodes radiating UVC 247-nanometre ultraviolet light.

Clogging material can be removed by a backflush ring of 24 Pentair X-flow ultra-filtration modules from R-14 to R-9. The filters take it in turn to be backflushed. This is happening at point R-10. Pressure drop at the chosen flow rate is low enough to give the option to use pairs of filters in series.

Clean, sterile water at a steady pressure of 80 bar goes through a rotating seal to a vertical row of spray heads containing 200 mm diameter silicon wafers each with 200 million submicron nozzles etched in silicon wafers starting at U-3. The rotating mizzen mast will track changes in direction of the apparent wind speed. The likely number of spray heads is 30 but the number in use will be adjusted to suit the available energy. Each spray head has a hatch that can be closed when it is not in use against an internal pressure of 7 bar. Four spray heads in the block diagram are at present not in use.

Each spray head, eg. U-3, has three Perkin Elmer blister valves which can operate without producing wear debris. One controls the incoming 80 bar salt-water flow. This will normally go out through the wafer nozzles provided that a second outlet blister valve is closed. But if at U-6, the inlet valve is closed and the outlet valve opened a third, normally-closed blister valve allows a flow of either filtered fresh-water or warm, filtered dry air to the *downstream* side of the silicon wafer to flow back out of the spray head so as to unclog blocked wafer nozzles. This can also or prevent salt drying out or ice freezing in them. Air for nozzle drying is driven by a turbine at Q-16 through a chiller to remove water vapour and then a warming element followed by two air filters through a valve at T-17 and then to all the spray heads. Fresh water for salt removal is desalinated at P-2.

At X-3 et al. each spray head contains a piezoelectric element as used in ultrasonic cleaners which can produce negative sawtooth pressures of -7 bar at 40 kilocycles when the hatch is closed and there is a water pressure of + 7 bar on the outer side of the wafer.

The change from normal spray operation to recirculation cleaning is controlled by a change-over valve at M-5. During recirculation, previously filtered water is pumped by the rubber squeeze tubes at O-9 and O-13 enough times until a particle sensor at M-1 shows a clean flow.

Solvents or Parylene vacuum cladding can be injected at point S-7 to seal in surface debris on internal walls. The water system can be drained by the valve at N-1

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