GENERAL FEATURES OF THE HYDRAULIC DISTRIBUTION SYSTEM

The Materials and Structural Testing Laboratory of University of Trento has installed a hydraulic distribution system, by Contract Competition, capable of providing a nominal oil flow of 1500 l/min on the main line \(v = 4.5 \text{ m/s}\) at the operational pressure of 21 MPa.

The hydraulic distribution system is made up by:

A) Two MTS “SilentFlo” hydraulic power units with variable flow labelled 505.150 equipped with variable-flow pumping system, each capable of providing 500 l/m at the operational pressure of 21 MPa.

B) An hydraulic distribution network composed of stainless AISI 316L steel pipes for outflow, return and drainage, sized for design operational flow at test pressure, with attachment to the two installed hydraulic power units and the predisposition for a future third pumping system, quick attachments for users, anti-vibration supports, expansion add-ons, accumulators.

C) Three flow-regulation and hydraulic-pressure units.

D) Electrical and electronic command, management and control equipment, with corresponding connection lines to the power switchboard of each power unit and to the distant control location, which allows remote control of the system from the Laboratory.

1. COMPOSITION OF THE HYDRAULIC DISTRIBUTION PLANT

Two hydraulic power units have been installed in service of the hydraulic distribution plant over-mentioned, each composed of:

1.1 Pump reservoirs and accessories

It is composed of a reservoir with gross capacity of 1893 l and minimum level of 1211 l.

1.2 Hydraulic power units with flow of 500 l/m

It is made up by two units, each with 5 pumps, for a total power of 225 kW. Each power unit absorbs 476 A at 380 VAC Hz.

1.2.1 Baseline functional requirements

The hydraulic power unit can be used with servo-controlled electro-hydraulic systems: the outflow varies automatically in response to the external distribution network. Both the pumping units can operate at two pressure states:

- low-pressure state (0.7-1 MPa);
- high-pressure state (21 MPa).

1.2.2 Principal components

Each pumping unit is composed of five pumps, driven by electrical motors. The variable-flow pumps allow an oil flow of 500 l/m; both units are endowed with pressure
and flow regulator devices and with solenoid valves for no-load start-up and pressure compensator. The units are equipped with proportional-control compensator that allows programming and varying the maximum operating pressure. In the outflow is installed a pressure filter with filtration degree equal to 10 microns and electronic dirty filter indicator. Each pumping unit is equipped with high-pressure manometers with bypass and with accumulators to handle peak flows. The two installed units are hydraulically connected and ready for a possible attachment to a third unit.

1.2.3 Vibration damping units

Each hydraulic power unit is endowed with anti-vibration supports in order to avoid the transmission of undesired vibration to the building works and the distribution network.

1.2.4 Line pressure-limitation units

Each MTS unit is equipped with mechanical calibration safety valves on each pump unit, set up to 22.4 MPa. On return collector is placed a pressure manifold with digital visualization, positioned on the control operator console, and a series of solenoid valves each able to initiate the discharge of a pump unit.

1.2.5 Auxiliary refrigeration and filtering unit

Oil filtering and refrigeration are obtained by passing the fluid returning to the tank by means of two stainless steel high-yield plate oil/water type heat exchangers, and through return filter with element of 3 µm. The stoppage electrical indicator placed on the return filter signals on the local and remote panels the need of replacing the cartridge.

The exchanger is able to dissipate 224 kW with cooling water having an input temperature of 15°C. The device is designed to maintain the oil in a range of temperature of between 45 °C and 56 °C.

1.2.6 Automatic closed-circuit water refrigeration plant

An automatic closed-circuit water refrigeration plant composed of two air-cooled refrigerator units outside placed and arranged for a third unit has been installed. Each unit is characterized by a refrigeration power of 50.7 kW, by an installed electrical power of 18.7 kW and a refrigerated water flow of 90/240 l/m obtained by means of two airtight compressor, automatic managed by microprocessor.

In the pumping room has been installed a mixed cooling plant made up by an exhaust convector and powered by one of the two refrigerator.

1.2.7 Noise level

A very care design has been performed to obtain the reduction of noise level, utilizing sound-absorbent devices: the pumping electrical motors are dipped in an oil-bath, so obtaining a maximum noise level of 71 dB(A).

2. HYDRAULIC DISTRIBUTION NETWORK

2.1 Routing and components
The hydraulic distribution are hanged to the reaction strong floor of the laboratory; six secondary vertical pipes rise inside the reaction wall. The connection of the pipes to the hydraulic pump, and the pipes itself, have been achieved through stainless AISI 316L steel pipes for pressure, output and drainage collectors.

In correspondence of the line attachment to the hydraulic distribution plants, of the bend at 90° under the reaction wall, between the horizontal collector manifolds and the starting blocks of the six vertical gaps flexible hoses have been placed to absorb vibrations and allow axial thermal dilatation of the steel parts.

Spherical closure valves, interposed between the pipe connection flanges, allow subdividing:
- all the six upright columns of the routes, each composed of three pipes: pressure, return and drainage;
- the horizontal distribution network in a point;
- the hydraulic distribution plant.

2.2 Sizing of the distribution networks

The distribution network is composed of pressure, return and drainage pipes; it has been sized to supply the maximum working capacity of 1500 l/m for the horizontal pressure and return pipes developing under the strong floor and of 1200 l/m for those placed vertically.

The pipes have been sized with the following criteria:
- pressure pipes: thickness-external diameter ratio no less then 0,11;
- maximum oil velocity of 4,5 m/s;
- maximum pressure loss, including valves, between the junction box and the most remote user point of 10% of the operating pressure.

There have been utilized:
- for the horizontal distribution network, 4” pipes for pressure (Sch. 160) and return (Sch. 40S) and 2” pipes for drainage (Sch. 40S);
- for the vertical distribution network, 3” pipes for pressure (Sch. 80) and return (Sch. 40S) and 1 ¼ “ pipes for drainage (Sch. 40S).

32 connections with 2” interception valves for pressure, 32 connections with 2” check valve for return and 32 connections with 1¼” check valve for drainage have been installed. All the attachments are endowed of rapid couplings compatible with the connections of the flow-regulation units and the operational hydraulic pressure.

In the terminal tracks of the network, at the end of the horizontal tract and in the columns, hydraulic distribution accumulators with capacity of 25 l at both the pressure and return ring, with air-release valves on both the pressure and return ring, valves for interception and discharging have been installed.

2.3 Oil for hydraulic circuit

It is utilized Mobil DTE 25 oil with the following characteristics:
- viscosity at 38° C: 215÷240 S.S.U.;
- particle count: ISO 13/10;
- % water: < 0.05;
- iron, ppm: < 30;
- silicon, ppm: < 15;
- copper, ppm: < 15.

The fluid should flow at an operating temperature range of: 40° ÷ 50° C.
3. FLOW-REGULATION AND HYDRAULIC PRESSURE LIMIT

Three new units designated “manifold” have been installed to be interspersed between the distribution line and the actuators by means of flexible hoses; a forth one was already available to the Laboratory. These devices permit to set the low-pressure level (7 MPa) independent of the downstream pressure level, raising up to 21 MPa. Each manifold is characterized by:

- connections for pressure and return (2") and drainage (3/8") for simultaneous control of two actuators;
- connections for pressure and return (2") and drainage (1/2") for the attachment to the distribution network;
- flexible hydraulic hoses 4 m and 6 m in length, with 2" diameter for pressure and return and ½" diameter for drainage;
- working pressure of 21MPa;
- minimum oil flow of 950 l/m;
- OFF/LOW (1 MPa) /HIGH (21 MPa) pressure control with solenoid valves;
- Accumulator on pressure of 20 l and on return of 8 l (1 l for pilot pressure);
- Pilot pressure for three-stage servo-valve and pressure for hydrostatic bearings;
- 25-micron principal filter, and 3-micron on the pilot line, with dirty filter indicators;
- connection cable to control electronics.

The “Manifold” units use the control software MTS Teststar 4.0.

4. ELECTRICAL COMMAND AND CONTROL EQUIPMENT FOR THE HYDRAULIC DISTRIBUTION PLANT

Each hydraulic power unit is equipped with local and remote panels, the first located on the pump itself whilst the second placed in a central position of the Laboratory. The panels allow the pumping control and signal possible functional anomalies. For safety reasons, when the remote control is able, the local one is disabled. The local control panel on the edge of the power uses a PLC (Programmable Logic Controller) able to manage the pumping unit and has the following functions:

- sequence of motors and control of breakdowns in the electrical circuits;
- pump supply with respect to the fluid overheating, fluid level, motor overloading, low pressure in line;
- hours of pump function;
- downstream pressure of each pump;
- tank level;
- oil temperature.

5. INSTALLATION – TESTING

The weldings of the pipes, curves and flanges have been performed by qualified personnel holding welders’ licenses. Particular care has been taken to the welding control on the pressure and return lines, which have been integrally tested with penetrating liquid and radiographies, part in the welding factory itself and the other in the Material and Structural Testing Laboratory. After oil washing and flushing phase, have been performed the leak tests on all the pipe lines, verifying that there wasn’t any pressure reduction after 24 hours; the required test pressure were:
• PRESSURE:  28 MPa;
• RETURN:    7 MPa;
• DRAINAGE:    2 MPa.

5.1 Putting into operation of the hydraulic distribution system

A circulation of the hydraulic distribution fluid for 15 consecutive days in all the branches of the distribution network at operational pressure equal to 21 MPa has been imposed, producing appropriate by-pass to connect the pressure pipes to the return pipes at the end of the lines. During this period, the oil temperature has been monitored and, at the end of the flow phase, the oil analysis has been performed by means of certified equipments, verifying that the cleaning level was falling within the requested limits (ISO 13/10).

5.2 Testing upon system delivery

The plant test has been performed by means of the following tests:

1. Quasi-static test

The two MTS actuators labelled 244.51 of +/- 1000 kN and 243.60 of + 650 kN and – 1000 kN owning to the Material and Structural Testing Laboratory, have been working simultaneously in semi-static modality utilizing the control software MTS Teststar 4.0. The following performances have been reached:
   • precision of 0,1% on the stroke of ± 250 mm;
   • maximum error allowed equal to 0,1% of the bottom of the delta load cell on a capacity equal to ± 1000 kN.

2. Dynamic test

The MTS dynamic actuator labelled 244.51 of +/- 1000 kN has been working with capacity of 680 l/m, with piston velocity of 23 cm/s and total stroke of 500 mm, utilizing the control software MTS Teststar 4.0. The following performances have been reached:
   • precision of 0,1% on the stroke of ± 250 mm;
   • maximum error allowed equal to 0,1% of the bottom of the delta load cell on a capacity equal to ± 1000 kN.
Appendix A

REPORT ON PROVISIONS, INSTALLATION AND TEST OF THE HYDRAULIC DISTRIBUTION SYSTEM

The provision phase began on 4th March 2002 with the drawing up of the contract undersigned by the University of Trento rector, prof. Massimo Egidi.

It’s not the first time that HYDROS has produced analogous plants, but in this case the engagement was particularly heavy either for hydraulic distribution system sizes and characteristics and for the difficulties connected to the building shape. The partnership with MTS System Srl was novel, charming, but completely to test.

In the Pavia workshop the technical office re-examined the design, defined only in a great extent, with particular care to the MANUFACTURING SCHEDULE. What was only a design, within the autumn had to become a perfectly working plant respectful of the tightening specifics requested by the University of Trento, with provision responsible Prof. Oreste S. Bursi.

MUST of the production order was INNOVATION based on the great experience acquired in previous productions, but overall with the use of absolutely reliable components and providers:

- SANDVICK for AISI 316L steel pipes
- OLEOTECNICA for AISI 316L steel flanges and tangs
- L.A.Z. Montaggi industriali for tang welding to the pipe
- C.R.C. Controlli radiografici C. for welding control by gamma-rays
- MHA Zentgraf GmbH for all the interception valves
- FASTER for screw rapid couplings, either on the pressure line or on the return one
- PROMATEC for high-pressure and low-pressure flexible hoses, with MANULI components
- CLIMAVENETA for the two refrigerators
- PALL - MP Filtri for the particle count analysers (according to NAS)
- MTS System Srl for the two hydraulic distribution systems Silent flow labelled 505.150 and the Manifolds labelled 293.32 with pertinent software.

All these companies had been informed about project characteristics and relevance: the involvement and responsibilization contributed to the delivery time respect and to maintain an high quality level of each component and so of the whole realization.

On Saturday 29th June the load of the first truck addressed to the Material and Structural Testing Laboratory of University of Trento was completed.
In the evening of the 8th July the two MTS hydraulic distribution systems labelled 505.150 had already been placed in the pumping room.

Two technician teams worked simultaneously looking one after the assembly of horizontal collectors (pressure line: 4” Sch. 160; return line: 4” Sch. 40; drainage line: 2” Sch. 40 – divided in three parts for a total of 80 m) and the other one after the six vertical gaps (pressure line: 3” Sch. 80; return line: 3” Sch. 40 and drainage line: 1”1/2 Sch. 40) installing 120 linear metres of pipes at all.

Because of the impossibility of using traditional lifting and transporting equipments, the installation into reaction floor internal spaces has been realized by means of special trolleys and lifts, able to work in narrow spaces, “ad hoc” produced by HYDROS.

The HYDROS, MTS System and UNIVERSITY OF TRENTO technicians have been involved in a common goal so creating a co-operation climate which produced very good results and allowed the full respect of established times. At the end of July the engine room, with two MTS hydraulic distribution systems and distribution network, was completed.

After completing the installation, the plant operating setting with the flow phase began. Two additional filters (rating 10µ, β=200) on the return and drainage lines were inserted to prevent the arrival to the two hydraulic distribution system tanks, already protected by filter on return line.
(rating 3µ, β=200), of any impurity present in the network. To justify the worries at the beginning of flow operations it must be reminded that the Mobil ESSO DTE 25 oil contained in the hydraulic distribution network is of about 2000 litres, which added to the capacity of the two tanks, each of 1700 l, reaches the total of 5400 l: all this considerable oil quantity had to be fluxed satisfying the NAS 4 class specifics.

At the same time HYDROS and MTS technicians verified the static network holding by putting in pressure separately first the six vertical gaps and after the whole distribution network (testing pressure in the pressure line: 28MPa; in the return line: 7MPa; in the drainage line: 2MPa). With reference to the plant flow, yet from the oil analyses carried out in the first two days in the most representative network points the fluid resulted in NAS 7 and NAS 6 classes. These values confirmed the design choice to use stainless pipes: by utilizing AISI 316L steel pipes and realizing a first TIG bead (head joint in class 1, see the attached welding notes), the tang welding bore clean and didn’t release impurities as calamine or carbon oxides as could happen by using common carbon steel pipes, later needing long flow times.

During the flow phase the two by-passes were moved, day by day, to the end of all the horizontal and vertical gaps. After a week, carrying out the analyses on the pressure and return collectors nearby the power units, are obtained the particle values characterized by NAS00 class and ISO 15/0/0 code.

After the network had been fluxed for a week at 1000 l/m through two duplex filtering elements on the pressure line (rating 10 micron, β=200) and on the return line (rating 3 micron, β=200) of the MTS power units, the cleaning level resulted so high that induced to believe to an anomaly of the laser MP Filtri LPA2 particle counter.

For a better guarantee on 13th September, at the official plant delivery, with the supervision of Mr. PASTORI, responsible of MP Filtri filter division, a second PALL analyser labelled PCM100 with serial number 424 tested and certificated by PALL in date 17/06/02 was used. The analyses carried out on the pressure, return and drainage lines (see attachment 8) utilizing the LPA2 analyser number 004647 of the MP Filtri and by the PALL PCM100 analyser certified the attainment of NAS 00 class.

The MTS technicians from Turin, with the collaboration of the engineers and technicians of the Material Structural Testing Laboratory of Mechanical and Structural Engineering Department of the University of Trento, completed the attachments of the TESTSTAR 4 digital controller to the two manifolds and to the MTS hydraulic actuators. Setting up has been verified and static and dynamic tests, in accordance to the specifics provided by the technical disciplinary, have been performed. In particular, the actuator behaviour and performances for linear velocity have been verified.
The MTS actuator labelled 244.51 of +/- 1000 kN, equipped with a three-stage servo-valve of 180 gpm, reached the velocity value with sinusoidal state requested in contract phase of 23 cm/s in accordance to correlated widths and frequencies: among several harmonicas, a sinusoidal function with frequency of 10 Hz has been applied.

Also the MTS actuator labelled 243.60 of +650 / -1000 kN, fundamentally designed for static tests, was able to fully satisfy the test specifics.

Finally a test in load control with the simultaneous application of cyclic loads by means of the two actuators has been performed, applying the load on expressly prepared contrast specimens.

The power units labelled 505.150, both endowed with 5 variable capacity pump units and with a device that optimises motor switching on and off in function of the requested capacity (“R.O.D.” Run On Demand system) so minimizing energetic efforts, were able to supply an overall flow of 1000 l/m at the constant nominal pressure of 3000 psi (207 bar).

On 23rd October 2002, with the positive test of the hydraulic distribution system, began the operative phase of the University of Trento hydraulic distribution system, … but the engagement of HYDROS and MTS technicians towards new goals hasn't been stopped.
NOTES FOR WELDING
STEEL PIPES
STAINLESS AISI 316L AND 316L

Date 25.11.02  Drawn by MANNA  Checked C.L.

WELDED HEAD JOINT CLASS 1

AZOTE WELDING: PIPE WITH ONE TIG PASSAGE, FILLINGS AND REFINISHES WITH 316L ELECTRODE

TIG process (Tungsten Inert Gas) with welding protective gas, argon pure at 99.99%.
To use TIG rods d=2mm.
The stainless AISI 316 L pipe weldings must be always executed with TIG system, plugging a pipe end with a spongy plug and flowing the gas inside from the opposite side (utilised gasses : Azote = 99% + Hydrogen or Argon 1%).
The TIG process is necessary to apply at the first passage, the followings can be executed with electrical arch welding processes with basical electrodes.
The welding, because it is protected from the bath sides, is devoid of defects, with a very good finishing of welding bead inside the pipes, even where there wouldn’t be possibility for further finishing touches.