Directional Control Valves - Series F
F130CF Constant-flow valve
F150CP Constant-pressure valve

Catalog 9129 8534-02
August, 1997 GB
Catalogue layout

This catalogue has been designed to give a brief overview of Series F valves, and to make it easy for you to study and choose from the different options available, so that we may customize your valve in accordance with your wishes. In addition to general information and basic technical data, the catalogue therefore contains descriptions of the options available for various so-called "function areas" of the valve.

Each function area is given as a subheading, followed by a brief description. When options are available for a function area, the subheading is followed by an "item number" in brackets, e.g. Main pressure relief valve [28]. This is followed by a series of coded options, e.g. PS, PB, Y, together with a brief description of what each code represents. Alternatively, one or more pressure, flow or voltage options are given.

On page 10 is a general circuit diagram showing the basic function areas in a F130CF valve and the item numbers that represent them. Naturally, the same item numbers are used for the respective function areas in all sub-circuit diagrams that appear elsewhere in the catalogue. Please note that, unless stated otherwise, all sections and views of the valves have been drawn as seen from the inlet section.

How to order your valve

The next step is to complete our so-called Customer Specification Form to specify the options and characteristics you wish to be incorporated into your valve. The Customer Specification Form contains the same item numbers that appear in brackets in this catalogue. To specify your valve, simply choose the common and spool-section specific options you require and enter the appropriate code or value into the box for the corresponding item number in the Customer Specification Form.

Should you require assistance completing the Customer Specification Form, please do not hesitate to contact your nearest VOAC representative, who will either help personally or refer you to the appropriate product specialist.

The information in your Customer Specification Form is then entered into our computerized valve specification program, which initiates the assembly process and generates a unique product ID number that is subsequently stamped into the data plate on your valve. Your valve specifications remain on our database to facilitate subsequent re-ordering or servicing of your valve.

Early consultation with VOAC saves time and money

Our experienced engineers have in-depth knowledge of the different types of hydraulic system and the ways in which they work. They are at your disposal to offer qualified advice on the best system for the desired combination of functions, control characteristics and economic demands. By consulting VOAC early in the project planning stage, you are assured of a comprehensive hydraulic system that gives your machine the best possible operating and control characteristics.

VOAC reserves the right to modify products without prior notice. Typical curves and diagrams are used in this brochure. Even though the brochure is revised and updated continuously, there is always the possibility of errors. For more detailed information about the products, please contact VOAC.

Conversion factors

1 kg = 2.2046 lb
1 N = 0.22481 lbf
1 bar = 14.504 psi
1 l = 0.21997 UK gallon
1 l = 0.26417 US gallon
1 cm³ = 0.061024 in³
1 m = 3.2808 feet
1 mm = 0.03937 in
9/5 °C + 32 = °F
Directional control valves  
Series F

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[00] refers to item numbers in the customer specification formula.
Series F stackable directional valves come in two basic versions: the F130CF for constant-flow (CFO) systems and the F150CP for constant-pressure (CP, CPU) systems. The valves are designed for many different applications, both mobile and industrial. They are used to control linear and rotary functions in machines such as cranes, excavators, front-end loaders, logging machines, refuse collecting vehicles, etc.

Compact system construction
Series F valves are of modular construction and offer unique possibilities to integrate application-adapted functions into the valve to give compact, total system solutions for hydraulically operated machines.

Great flexibility in machine design
Series F valves can be equipped for either direct or remote control, the latter by means of pneumatic, hydraulic, or electric signals, or combinations thereof. Combined direct and remote control is also possible.

Economy
Thanks to their modular construction, Series F valves can be optimized for both simple and complex functions. Comprehensive function-integration possibilities give low overall system costs. Ease of alteration or expansion enables individual customization demands to be met without difficulty.

Compactness, serviceability and safety
Series F valves are of robust construction, with each function integrated so that the valve remains a single unit. The resultant reduction in the number of components, hoses and cables greatly facilitates servicing and the training of personnel. The F130CF can be equipped with a special inlet section that enables the incorporation of a simple and effective emergency STOP device for the functions it controls, thus meeting the demands of the EC Machinery Directive.

Design
Series F stackable valves can be supplied with 1-11 spool sections and in combination with manifold-type function blocks. The valves are designed for system pressures of up to 320 bar and can be equipped with port relief valves in the service ports for a maximum pressure of 350 bar. The maximum recommended pump flow for the F130CF is 110 l/min (depending on the choice of spool) and 150 l/min for the F150CP. A very wide range of control spools for the valves enables optimal adaptation of control characteristics.

Essential characteristics
- Low lever forces give ergonomic comfort when valve is controlled manually.
- Modular construction enables easy subsequent alteration or expansion of the valve.
- Great manufacturing precision permits spools to be changed easily at any time.
- Special, manifold-type function blocks for flanging to Series F valves enable even more functions to be integrated into the unit, thus giving compact system dimensions with minimal external piping.
- Special mid-inlet section facilitates compact system construction, even in systems with several pressure levels.
- Accessories for adapting the valves for use in both multi-pump and multi-valve systems increase their ranges of application in many different kinds of hydraulic system.
- Wide range of spool actuators gives great system design possibilities.
- Exceptionally wide range of application-adapted spools enables individual control characteristics to be optimized.
- Proportional remote controls have pressure compensated spools, which further improve control and simultaneous-operation characteristics.
- Separate check valves in each section prevent undesirable load sinking.
- Separate port relief valves in each service port enable port-specific pressure adaptation.
- Excellent characteristics of port relief valves, even as secondary pressure relief valves, respond very quickly to sudden load changes and enable port-specific pressure limitation.
- Low pressure drops keep energy losses down.
- Machined control edges in the valve housing further improve the control characteristics.
- High quality materials and great manufacturing precision assure quality products with low internal leakage and long service life.
- Simple design makes the valves easy to service.
- Wide range of accessories such as levers, connectors and electric, hydraulic and pneumatic remote-control components enable the system to be tailored exactly to your needs.
**Directional control valves Series F**

**System descriptions**

**Principle circuit diagram for CFO system.**

**Constant-flow systems (CFO)**

In constant-flow systems, the flow is constant for a given engine speed, while the pressure is adapted according to need.

The CFO system is the most widely used system in mobile machines. Compared with other systems, it has less complicated components and is therefore relatively insensitive to contaminants in the oil. Oil that is not directed to a consumer is pumped back to tank via the free-flow gallery in the valve. When several lift functions are operated simultaneously, the pressure is determined by the heaviest load. Simultaneously operated functions should therefore have approximately the same pressure needs, or should be divided into separate circuits in order to minimize the influence between simultaneously operated functions and give good operating economy. As long as the majority of pump capacity is being consumed, the system gives very good operating economy. For this reason, it is important to have a correctly dimensioned pump.

**Control characteristics**

When manually controlling CFO systems the speed of the load is not a directly related function of the lever stroke. Speed is determined by the size of the load, direction of force, direction of movement, other simultaneously operated loads and by the pump flow. This is because, as more service ports are opened, the flows redistribute themselves so that the pressure drop in all the flow paths is equal. By means of application-adapted spools, however, considerably better simultaneous operational characteristics can be obtained. In some cases, this can result in higher energy losses during fine metering. In certain applications, this characteristic is exploited by giving the operator a sense of the weight of the load being handled (so-called "force sensing").

In several VOAC proportional remote-control systems, the control spool is pressure compensated. This means that the regulated flow rate remains constant for a given lever stroke, regardless of pressure variations (speed control).

**In the F130CF with hand-operated spools, the speed is influenced by the size of the load, i.e. the heavier the load, the longer the lever stroke needed before the load starts to move.**

**In the F130CF with PC and EHC closed spool actuators, the spools are pressure compensated, which means that the influence of the load on speed is minimal.**
Principle circuit diagram for CPU system

**Constant-pressure systems (CP)**

In a CP system, the pressure is constant while the flow is varied according to need. The constant-pressure system is of simple construction with uncomplicated components. The pump generally has variable displacement that is regulated to keep the pressure constant. It should be dimensioned to give the sum of the maximum flows for simultaneously operated functions. The system is less sensitive to pressure drops, since a pressure corresponding to the capacity limit of the machine is always available.

**Unloaded constant-pressure systems (CPU)**

To save energy and avoid so-called “creeping” while travelling between sites, there is a variant of the CP system called a CPU system, in which a hydraulic signal from the valve to the pump causes the pump to adopt the rest position. As soon as a control spool is actuated, the pump gives maximum pressure. The F150CP can be used as efficiently in CPU systems as in CP systems.

**Control characteristics**

With a correctly customized F150CP valve, the system is given very good control characteristics and different functions do not affect each other. The system has good anti-cavitation characteristics, which means that a lowering movement can be changed to a lifting movement without delay. The maximum speed of each function is determined by the design of the spool and by the pressure demands of the load. In the F150CP too, remote controlled spools are pressure compensated. However, if the flow requirements of the system exceed the maximum capacity of the pump, the pressure level cannot be maintained and the normally very good control characteristics deteriorate.
System connection
When there are more than one valve and one pump in a system, connection can be effected in different ways. A number of connection examples are given below.

A. Power beyond connection (F130CF)
The pump is connected to valve one. Flow that is not directed to a function via the first valve continues on to the subsequent valve. In this way, priority is effected. In the event of full spool actuation, no flow continues to the subsequent valve.

If an additional pump is connected to valve 2, then valve 2 receives the flow from pump 2 plus any residual flow from valve 1.

B. Parallel connection
In parallel connection, the same pump is connected to several valves. This arrangement works as though the pump were connected to a single large valve.

Parallel connection F130CF:

Parallel connection, constant pressure (CP), F150CP
Parallel connection, unloaded constant pressure (CPU), F150CP

The various adaptors are described in more detail on pages 12 and 16.
### Technical data

#### Pressure

- **Pump connection**: max. 320 bar* 4640 psi
- **Service port**: max. 350 bar* 5075 psi
- **Tank connection, static**: max. 10 bar 145 psi

* Stated pressures are maximum absolute shock pressures at a tank pressure of 10 bar (145 psi)

#### Flow rates (recommended)

- **F130CF, pump connection**: max. 110 l/min** 30 USgpm
- **F150CP, pump connection**: max. 150 l/min 40 USgpm
- **Return from service port**: max. 175 l/min 46 USgpm

** Max. recommended flow rate is dependent on choice of spool.

#### Feed reducer (F150CP)

- **Adjustment range**: 20-220 bar 290-3190 psi

#### Internal pilot pressure

- **Fixed settings**: 35 bar (507 psi) for ESO and ESP actuators
- **25, 35 or 50 bar (363, 507 or 725 psi)** for EHC spool actuator

#### Leakage from service port over spool

- From A or B port: max. 12 cm³/min (0.73 in³/min) at 100 bar (1450 psi), 50 °C and viscosity 30 mm²/s (cSt)

#### Connections

- **All standard connections are available in two versions (unless stated otherwise): G-version (BSP) for flat seal (type Tredo) in accordance with ISO 228/1 and UN-version for O-ring seal in accordance with SAE J1926/1.**

- **Service ports are available in two different sizes.**

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<table>
<thead>
<tr>
<th>Connection</th>
<th>Location</th>
<th>G-version</th>
<th>UN-version</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2</td>
<td>Inlet section</td>
<td>G 3/4</td>
<td>1-1/16-12 UN-2B</td>
</tr>
<tr>
<td>PM</td>
<td>Mid-inlet</td>
<td>G 3/4</td>
<td>1-1/16-12 UN-2B</td>
</tr>
<tr>
<td>T1</td>
<td>End section</td>
<td>G 3/4</td>
<td>1-1/16-12 UN-2B</td>
</tr>
<tr>
<td>T2</td>
<td>Inlet section</td>
<td>G 1</td>
<td>1-5/16-12 UN-2B</td>
</tr>
<tr>
<td>TM</td>
<td>Mid-inlet</td>
<td>G 1</td>
<td>1-5/16-12 UN-2B</td>
</tr>
<tr>
<td>Service ports</td>
<td>Spool section</td>
<td>G 1/2</td>
<td>7/8-14 UNF-2B</td>
</tr>
<tr>
<td>or</td>
<td>Spool</td>
<td>G 3/4</td>
<td>1-1/16-12 UN-2B</td>
</tr>
</tbody>
</table>

#### Weight

- **Weight varies somewhat depending on the configuration of the valve. The information given below is therefore approximate.**

#### Valve housing inclusive of spool, pressure relief valve etc; but exclusive of spool actuators.

- **Inlet section**: 4.4 kg 9.7 lb
- **Double spool section**: 9.6 kg 21.2 lb
- **Single spool section**: 4.7 kg 10.4 lb
- **Mid-inlet**: 4.2 kg 9.3 lb
- **Spool outlet section**: 6.9 kg 15.2 lb
- **End section**: 4.7 kg 10.4 lb

#### Spool actuators

- **C, ACP2**: 0.3 kg 0.7 lb
- **B3, DPOL**: 0.4 kg 0.9 lb
- **PC**: 0.5 kg 1.1 lb
- **DTPOL**: 0.7 kg 1.5 lb
- **CB, TPOL, ACP2**: 0.8 kg 1.8 lb
- **ACE2, ACE2F**: 1.1 kg 2.4 lb
- **ECO, ECP**: 1.2 kg 2.6 lb
- **EHC**: 2.4 kg 5.3 lb
Environmental characteristics
While the valve can be mounted in all conceivable directions, care should be taken to ensure that spool ends on open spool actuators are not subjected to heavy soiling. The base should be flat and stable so that the valve is not subjected to strain. If the valve is mounted with the cap of the spool actuator facing downwards, then cap A13 should be chosen for spool actuators C and B3 [35].

The O-rings in the valve are of nitrile rubber. Several special variants in Viton are available - please contact your nearest VOAC representative for further information. For the F150CP, it is recommended that A30 [27] is chosen (Viton O-rings in the parting surfaces between the sections), since Viton withstands heat better than nitrile rubber. (It should be noted that a lot of heat is developed in hard-working constant-pressure systems.)

Temperature
Oil temperature, function range -20 °C to 90 °C
Oil temperature, working range +20 °C to 90 °C

Filtration
Filtration must be arranged so that Target Contamination Class 18/14 according to ISO 4406 is not exceeded. For the pilot circuit, Target Contamination Class 18/19 according to ISO 4406 must not be exceeded.

Hydraulic fluids
The best performance is obtained if mineral-base oil of high quality and cleanliness is used in the hydraulic system.

Hydraulic fluids of type HLP (DIN 51524), oil for automatic gearboxes Type A and engine oil type API CD can be used. Synthetic, fire-resistant and environmentally friendly oils can also be used. If in doubt about the suitability of an oil, please contact your nearest VOAC representative for information.

Viscosity, function range 15-6000 mm²/s
(at start-up)
Viscosity, working range 15-380 mm²/s

Technical information in this catalogue applies to a viscosity of 30 mm²/s and temperature of 50 °C.

Pressure drop
Pressure drop with the pump-unloading inlet

\[
\Delta p \text{ (bar)} \quad \text{Pressure drop P1 to T2, 6-section valve}
\]

Unactivated solenoid
Activated solenoid

Pressure drop with standard inlet (F130CF)

\[
\Delta p \text{ (bar)} \quad \text{Pressure drop P1/P2 to T1}
\]

Pump unloading function.
See description and hydraulic circuit diagram on page 12. With the pump-unloading inlet, the pressure drop does not fall below 5 bar thanks to a counterpressure valve that guarantees the function. Pressure-drop curves T1 to T2 include an extra counter-pressure of 2 bar at a flow of 100 l/min due to a pressure drop over the check valve in the inlet. If the check valve is not chosen, the pressure drop is reduced by the corresponding value.
The circuit diagram above shows the F130CF with three spool sections and an mid-inlet between sections 2 and 3.

The item numbers in the hydraulic circuit diagram above and in the table below refer to the function areas for which different options are available. The valve above is equipped as described below. For details of other options for the F130CF, as well as those available for the F150CP, please refer to the respective function areas [item numbers] given alongside the sub-headings from page 12 onwards.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>N2</td>
<td>Free-flow pump gallery with check valve.</td>
</tr>
<tr>
<td>7</td>
<td>PS</td>
<td>Adjustable main pressure relief valve in mid-inlet.</td>
</tr>
<tr>
<td>10</td>
<td>PM</td>
<td>Pump connection in mid-inlet open.</td>
</tr>
<tr>
<td>11</td>
<td>TMB</td>
<td>Tank connection in mid-inlet plugged.</td>
</tr>
<tr>
<td>21</td>
<td>P1B</td>
<td>Pump connection P1 in inlet plugged.</td>
</tr>
<tr>
<td>22</td>
<td>P2</td>
<td>Pump connection P2 in inlet open and without supplementary adaptors.</td>
</tr>
<tr>
<td>23</td>
<td>T1B</td>
<td>Tank connection T1B in end section plugged. Free-flow gallery connected to tank.</td>
</tr>
<tr>
<td>24</td>
<td>T2</td>
<td>Tank connection in inlet open.</td>
</tr>
<tr>
<td>28</td>
<td>PS</td>
<td>Adjustable main pressure relief valve in inlet.</td>
</tr>
<tr>
<td>32</td>
<td>D</td>
<td>Spool for double-acting function in sections 1 and 2.</td>
</tr>
<tr>
<td></td>
<td>EA</td>
<td>Spool for single-acting function served by service port A; service port B blocked in section 3.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>C</td>
<td>Stepless, hand-operated spool actuator with spring centring (on all sections).</td>
</tr>
<tr>
<td>37</td>
<td>LM</td>
<td>Bracket for hand lever fitted.</td>
</tr>
<tr>
<td>38</td>
<td>N</td>
<td>Load-hold check valve in each section to prevent undesirable sinking of the load.</td>
</tr>
<tr>
<td>40</td>
<td>PA</td>
<td>Combined port-relief and anti-cavitation valve in service port A in all sections.</td>
</tr>
<tr>
<td>43</td>
<td>Y</td>
<td>Connection service port B to tank gallery blocked in section 1.</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Anti-cavitation valve fitted in service port B, section 2.</td>
</tr>
<tr>
<td></td>
<td>X1</td>
<td>Connection service port B to tank gallery open in section 3 (always the case with EA spool).</td>
</tr>
</tbody>
</table>
The inlet section comes in two basic versions: the standard version and a version with integrated pump unloading. The latter version can be used with the F130CF only. The standard inlet section has two pump connections, P1 and P2, and a tank connection, T1. A number of different adaptors can be fitted in the P2 connection for various system functions. The standard inlet section also contains the main pressure relief valve.

The inlet section with integrated pump unloading contains the pump unloading functions and main pressure relief valve, a pump connection P1 and tank connection, T2.
Directional control valves  

Inlet section with integrated pump unloading [12]

With its pump unloading function and some form of overcentre valve, this inlet section enables machines to be equipped with an emergency STOP function.

According to the EC Machinery Directive, machines must be equipped with one or more emergency STOP functions to enable actual or impending danger to be averted.

“The emergency STOP device must be clearly identifiable and visible with quick and easy access. It must stop the dangerous process as quickly as possible, without creating additional hazards.”

Furthermore, it is anticipated that amendments to the directive will soon require the energy supply to the function to be cut off by the emergency STOP device. The inlet section in the valve opposite includes an integrated function that cuts off the energy supply to the valve sections.

In the event of a hose rupture it is also important that the environmental and economic issues are considered. It is therefore important the tank gallery is shut off to prevent oil running out from the tank via the anti-cavitation valves.

N.B. Since the pump unloading function forms part of the machine safety system, please refer also to separate printed matter No. 9129 8561-42: Installation instructions for inlet section with integrated pump unloading.

The electromagnet that controls the pump unloading function is available in 12 and 24 VDC versions. The connector is of type AMP Junior-Timer type C, 963040-3 or Bosch 1928 402 404. The electromagnet is equipped with a manual override facility for use in emergencies.

- **E12** Inlet with integrated pump unloading function for 12 V system.
- **EX12** Inlet with integrated pump unloading function - without check valve in tank gallery - for 12 V system.
- **E24** Inlet with integrated pump unloading function for 24 V system.
- **EX24** Inlet with integrated pump unloading function - without check valve in tank gallery - for 24 V system.

**Pump connection P1** [21]

- **P1** Pump connection P1 open. Common version.
- **P1B** Pump connection P1 plugged.

**Pump connection P2** [22]

The inlet section with the pump unloading function does not have the P2 connection. See page 7 for more details about the use of different adaptors.

- **P2** Pump connection P2 open.
- **P2B** Pump connection P2 plugged. Common version for F130CF.
- **L** Parallel-connection adaptor; used in F130CF when valve is connected “downstream” of another valve.
- **CUI** Constant-pressure adaptor; used in F150CP in CPU systems to direct unloading signal to pump regulator. Signal is taken from pump connection via a diam. 0.8 mm restrictor. Common version for F150CP.
- **CUI2** Constant-pressure adaptor with same function as CUI, but with diam. 1.5 mm restrictor.
- **LSI** Constant-pressure adaptor without restrictor. Used in F150CP, e.g. in CPU systems if pump unloading signal is taken from alternative valve.
Directional control valves

**Tank connection T2 [24]**

- **T2** Tank connection T2 open. Common version for F150CP.
- **T2B** Tank connection T2 plugged. Common version for F130CF.
- **T2R** Tank connection T2 reduced by means of reducer adaptor to thread size G 1/4 or 9/16-18 UNF-2B.

**Main pressure relief valve [28-31]**

The pressure relief valve is direct-acting and steplessly adjustable. For best characteristics, the working range is divided into 7 different intervals: 80-125 bar, 126-140 bar, 141-160 bar, 161-210 bar, 211-250 bar, 251-280 bar and 281-320 bar. It is possible to increase the opening pressure by about 30 bar over the maximum value of the adjustment range to enable testing of the machine at a pressure higher than its maximum working pressure. The VOAC PLD130 cartridge valve, which has very good characteristics, is used as the pressure relief valve. As an alternative to the pressure relief valve, a plug can be fitted to block the pump-to-tank connection, e.g. when the main pressure relief valve is located elsewhere in the system.

**Main pressure relief valve [28]**

- **PS** Adjustable main pressure relief valve. Setting made at the factory.
- **PB** Adjustable main pressure relief valve. Delivered factory-set and sealed.
- **Y** Without pressure relief valve.

**Pressure setting [29]**

- Max. 250 bar for valves in grey-iron version.
- Max. 320 bar for valves in nodular-iron version.

**Pressure-setting flow [30]**

- **1** Pressure setting made with a flow of 20 l/min through the pressure relief valve. Common version.
- **60** Pressure setting made with a flow of 60 l/min through the pressure relief valve. Option for applications in which there are very high demands on maximum system pressure.
A mid-inlet is available for the F130CF. Many compact system solutions can be obtained with the aid of the mid-inlet, in which there is a pump connection PM and a tank connection TM. The mid-inlet can be supplied with or without a check valve in the free-flow gallery. Alternatively, it can drain the pump flow in the free-flow gallery from upstream spool-sections to tank. The main pressure relief valve can be fitted in the mid-inlet section, depending on the way in which the system is constructed. See connection alternatives (next page). Several mid-inlets can be placed in one and the same valve to give optimum system construction.
Directional control valves

Pump gallery [6]
/ Mid-inlet with free-flow pump gallery; Power beyond connection; single pump operation.
N2 Mid-inlet with free-flow pump gallery equipped with check valve; Power beyond connection; dual pump operation.
Y2 Mid-inlet without free-flow pump gallery. Two separate pump circuits.

Main pressure relief valve [7]
The same main pressure relief valve that is mounted in the inlet section can also be mounted in the mid-inlet section. See item [28] (inlet section) for more information and technical data.
PS Adjustable main pressure relief valve. Setting made at the factory.
PB Adjustable main pressure relief valve. Delivered factory-set and sealed.
Y Without pressure relief valve.

Pressure setting [8]
Max. 250 bar for valves in grey-iron version.
Max. 320 bar for valves in nodular-iron version.

Pressure-setting flow [9]
/ Pressure setting made with a flow of 20 l/min through the pressure relief valve. Common version.
60 Pressure setting made with a flow of 60 l/min through the pressure relief valve. Option for applications in which there are very high demands on maximum system pressure.

Pump connection PM [10]
PM Pump connection PM open. Common version.
PMB Pump connection PM plugged.

Tank connection TM [11]
TMB Tank connection TM plugged.

Mid-inlet section with free-flow gallery with Power beyond connection for single pump operation (/). In systems in which several different pressure levels are required, main pressure relief valves can be fitted for different pressure levels before and after the mid-inlet.

Mid-inlet section with check valve for Power beyond connection and multi-pump operation (N2). Surplus pump flow in the inlet section is used by the sections downstream of the mid-inlet.

Mid-inlet section for separate pump circuits (Y2). If an extra tank line is connected to the mid-inlet, the pressure drop from pump to tank is reduced.
The end section is available in two different versions: one with only one tank connection T1 [23] and the other in which the end section is combined with a spool section to give a so-called spool outlet section. This is used instead of an end section in combination with single spool section to give a more compact, cost-effective valve. In addition to the service ports, the spool outlet section is equipped with a tank connection T1 [23]. A number of different adaptors can be fitted in the T1 connection to give various system functions.

**Counterpressure valve / tank connection T1 [23]**

<table>
<thead>
<tr>
<th>T1</th>
<th>Tank connection T1 open. Common version for F130CF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1B</td>
<td>Tank connection T1 plugged.</td>
</tr>
<tr>
<td>T1R</td>
<td>Tank connection T1 reduced to thread size G 1/4 or 9/16-18 UNF-2B by means of reducer adaptor.</td>
</tr>
<tr>
<td>PT</td>
<td>Adjustable counterpressure valve. Raises pressure in free-flow gallery. Adjustment range: 6-12 bar. Delivered factory set: 7 bar at q = 75 l/min. Tank connection T2 must be open - T2 [24]. PT can only be used with remote operated F130CF valves. It is used to raise the pressure level in the free flow gallery with all the spools in the neutral position. This is required to generate sufficient pressure to start spool movement when the pilot pressure for the remote control spools is fed via a pressure reducer and the same pump.</td>
</tr>
<tr>
<td>B</td>
<td>Blocking adaptor. Blocks free-flow gallery's tank connection. Used in F150CP only and always used if there are no subsequent valves. (When there are subsequent valves, R-adaptor is used instead.) B is Common version for F150CP.</td>
</tr>
<tr>
<td>S</td>
<td>Power beyond connection adaptor used to block connection between free-flow gallery and tank, while free-flow gallery flow is directed to subsequent valve via T1 connection.</td>
</tr>
<tr>
<td>R</td>
<td>Signal-transmission adaptor for F150CP in CPU systems. Used instead of S-adaptor when subsequent valves are connected. Connection thread in T1 is reduced to G 1/4 or 9/16-18 UNF-2B.</td>
</tr>
</tbody>
</table>
Spool section

Series F valves are stackable and can be supplied in combinations of 1 to 11 spool sections. Each spool section can be equipped individually with a large number of different optional functions, spools and spool actuators for optimal adaptation to the application and controlled function. To give the best economy, spool sections are available in three basic versions:

- double spool section for two spools
- single spool section for one spool
- single spool section in combination with an end section.

Moreover, spool sections are available in two different materials: grey iron, for a maximum pump pressure of 250 bar; nodular iron, for a maximum pump pressure of 320 bar.

Spool actuators [35]

A large number of spool actuators are available for Series F valves. They are divided into three different groups: hand operated, ON/OFF remote controlled and proportionally remote controlled.
Directional control valves Series F

Hand-operated spool actuators with open spool end

C  Spring-centred spool actuator.
   Stepless actuator with spring return to neutral position.

B3  3-position spool actuator.
   The B3 actuator has 3 mechanically detented positions:
   neutral and fully actuated at either end position. The
   spool remains in the selected position and must be
   moved mechanically from one position to another.

C+A13  Spool actuator C/B3 with special cap furnished with
       extra drainage holes.
   C+A13 or B3+A13 are used when the valve is mounted
   in such a way that the cap of the spool actuator points
   downwards. In the standard cap, drainage is towards
   the directional valve. The A13 version also has drainage
   holes in the bottom.

CB  Float-position spool actuator.
   The CB is a special spool actuator for F-spoons (see
   page 25). It is of the stepless type with spring return
   from the two normal end positions to neutral, and has a
   mechanically detented fourth position at one extreme
   end. The spool remains in the fourth position and must
   be moved out of it mechanically.

TPOL  Spring-centred spool actuator with overload protection
       facility.
   The TPOL actuator is of the stepless type with spring
   return to neutral. It is furnished with a connection to
   which the signal line from a load-limiting device can be
   connected. The signal forces the spool into neutral. For
   the spool to be actuated again, the moment of the
   dangerous load must be reduced.
   On receipt of the overload signal, the TPOL actuator
   breaks the connection "pump to service port A".
   Connection thread: G 1/4 or 9/16-18 UNF-2B.

DPOL  Spring-centred spool actuator with overload protection
       facility.
   The DPOL actuator works in the same way as the TPOL
   but, on receipt of the overload signal, breaks the con-
   nection "pump to service port B".
   Connection thread: G 1/4 or 9/16-18 UNF-2B.

DTPOL  Spring-centred spool actuator with overload protection
       facility.
   The DTPOL actuator works in the same way as the
   TPOL and DPOL actuators, but can break either the
   "pump to service port A" or "pump to service port B" con-
   nection.
   Connection thread: G 1/4 or 9/16-18 UNF-2B.

* See page 22.
Remote controlled ON/OFF spool actuators with open spool end and hand operating facility

**AC2**
- Pneumatic ON/OFF spool actuator.
- The AC2 is a pneumatically controlled ON/OFF spool actuator with spring centering and the possibility of stepless control by means of a hand lever.
- Control pressure: **min. 4 bar**
- **max. 10 bar.**
- Connection thread: G 1/8 or NPTF 1/8-27

**ACE2**
- Electro-pneumatic ON/OFF spool actuator.
- The ACE2 is an electro-pneumatically controlled ON/OFF spool actuator with spring centering and the possibility of stepless control by means of a hand lever.
- Primary air: 4-10 bar
- Control current: (12 VDC) min. 850 mA
- (24 VDC) min. 420 mA
- Voltage tolerance: ±20%
- Connection thread: G 1/8 or NPTF 1/8-27

**ACE2F**
- Electro-pneumatic ON/OFF spool actuator.
- The ACE2F is identical to the ACE2 except that it has a common supply gallery for primary air. The primary air can be connected to either the last or the first valve section that is equipped with an ACE2F spool actuator.
- Connection thread: G 1/8 or NPTF 1/8-27

**ACE2+ A58**
- ACE2 or ACE2F spool actuator with special cable connector. The ACE2+ A58 or ACE2F+ A58 are supplied with cable connectors equipped with light-emitting diodes.

**ESO**
- Electro-hydraulic ON/OFF spool actuator.
- The ESO is an electro-hydraulically controlled ON/OFF spool actuator with spring centering to neutral and the possibility of stepless control by means of a hand lever.
- The VOAC cartridge valve ODC25 is used as a converter valve.
- The connector is not supplied with the valve. Suitable connectors are: AMP Junior-Timer type C, 963040-3 or Bosch 1928 402 404.
- Control current: (12 VDC) min. 940 mA
- (24 VDC) min. 475 mA
- Voltage, 12 V systems: max. 14 V 100% ED
- max. 16 V 50% ED
- 24 V systems: max. 28 V 100% ED
- max. 32 V 50% ED
- Coil resistance at +20 °C:
  - (12 V) 53 Ω
  - (24 V) 21.2 Ω
- Connection thread: G 1/4 or 9/16-18 UNF-2B.

See also page 23.
Remote controlled, proportional spool actuators with open spool end and hand operating facility

ACP2  Pneumatic proportional spool actuator.

The ACP2 is a pneumatically controlled, proportional spool actuator with spring centring and the possibility of stepless control by means of a hand lever. The ACP2 is best controlled by the VOAC VP04 remote control valve (see separate brochure).

Breakaway pressure*: 2.5 bar
Final pressure*: 7 bar (max. 10 bar)
Connection thread: G 1/8 or NPTF 1/8-27

ESP  Electro-hydraulic proportional spool actuator.

The ESP is an electro-hydraulic, proportionally controlled spool actuator with spring centring and the possibility of stepless control by means of a hand lever. The VOAC PVC25 cartridge valve is used as a converter valve.

ESP are best controlled by means of a VOAC electric remote-control system (see separate brochure).

A connector is not supplied with the valve. Suitable connectors are: AMP Junior-Timer type C, 963040-3 or Bosch 1928 402 404.

Voltage

<table>
<thead>
<tr>
<th>Voltage</th>
<th>12 V</th>
<th>24 V</th>
</tr>
</thead>
</table>

Breakaway starting current*: max. 460 mA max. 225 mA
Final current*: min. 970 mA min. 480 mA
Tank pressure: max. 15 bar max. 15 bar
Solenoid (PVC25): max. 1450 mA, max. 730 mA, 100% ED 100% ED

Coil resistance at +20 °C: 5.4 Ω 21.7 Ω
Inductance: 27.7 mH 7.0 mH

Connection thread: G 1/4 or 9/16-18 UNF-2B.

See also page 23.
Remote controlled, proportional spool actuators with closed spool end

**PC1**
Hydraulic proportional spool actuator.

The PC1 and PC2 are hydraulically, proportionally controlled, spring-centred spool actuators. The PC1 is used on the F130CF with pump flows up to 80 l/min. The PC2 is used on the F130CF with pump flows above 80 l/min and on the F150CP. The PC1 and PC2 are best controlled by the VOAC PCL4 remote control valve (see separate brochure).

- **Breakaway pressure**: PC1 6 bar, PC2 7 bar
- **Final pressure**: PC1 16 bar, PC2 26 bar (max. 35 bar)

Connection thread: G 1/4 or 9/16-18 UNF-2B.

**PC1+ A03**
This indicates that the PC1 or PC2 is equipped with an adjustment screw for stepless limitation of the spool stroke.

*The "breakaway pressure" and "breakaway starting current" refer to the pressure/current needed for the directional valve to open the connection "pump to service port". The "final pressure" and "final current" are the lowest pressures/currents needed to effect full actuation of a spool in the directional valve. This data must be taken into consideration when choosing converter valves, since the opening pressure/current of the converter valve must be lower than the breakaway pressure/current of the spool actuator in order to avoid jerky starting and stopping. Moreover, the converter valve's final pressure/current must be higher than the final pressure/current of the directional valve in order to ensure that the directional valve can be fully actuated. This is extremely important on the F130CF because, if the spool is not fully actuated, the free-flow gallery will not close, with the result that a certain amount of flow will go directly to tank instead of going to the consumer. This must also be taken into consideration in the case of stroke-length limitation of the PC1, PC2, EHC1 and EHC2 spool actuators by means of the special stroke-length limitation screw.*

**EHC1**
Electro-hydraulic proportional spool actuator.

The EHC1 and EHC2 are electro-hydraulically, proportionally controlled, spring-centred spool actuators. The EHC1 is used on the F130CF with pump flows up to 80 l/min. The EHC2 is used on the F130CF with pump flows above 80 l/min and on the F150CP. The EHC1 and EHC2 are best controlled by means of a VOAC electric remote-control system (see separate brochure). The VOAC PV102 is used as a converter valve.

- **Voltage**: EHC1 12 V, EHC2 12 V
- **Breakaway starting current**: max. 400 mA, max. 440 mA
- **Final current**: min. 730 mA, min. 1100 mA
- **Pump pressure**: max. 35 bar, max. 35 bar
- **Tank pressure**: max. 15 bar, max. 15 bar
- **Solenoid (PVE102)**: max. 1250 mA, 100% ED
- **Coil resistance at +20 °C**: 7.2 Ω, 7.2 Ω
- **Inductance**: 10 mH, 10 mH

**PC2+ A03**

**EHC1 EHC2**

**Voltage**: 24 V, 24 V

- **Breakaway starting current**: max. 220 mA, max. 240 mA
- **Final current**: min. 400 mA, min. 600 mA
- **Pump pressure**: max. 35 bar, max. 35 bar
- **Tank pressure**: max. 15 bar, max. 15 bar
- **Solenoid (PVE102)**: max. 680 mA, 100% ED
- **Coil resistance at +20 °C**: 24.6 Ω, 24.6 Ω
- **Inductance**: 32 mH, 32 mH

Connection thread: G 1/4 or 9/16-18 UNF-2B.
Lever bracket [37]

**LM**  Bracket for hand lever fitted. Hand lever not supplied. Please order lever separately. See page 29.

**LM+A04**  Bracket LM turned through 180°. Note: With this arrangement, the same lever movement activates the opposite service port.

**LU**  No bracket for hand lever. Open spool end.

**X**  No bracket for hand lever. Closed spool end. Always the case with EHC1, EHC2, PC1 and PC2 spool actuators only.
ESO/ESP spool actuators [42A] [45A] [47] [48] [49] [50]

ESO and ESP spool actuators [35] can be equipped with accessories that affect not only one, but several spool sections, e.g. integrated reducer valve, connection plates and bleed-off restrictor for heating up the oil.

All connections: G 1/4 or 9/16-18 UNF-2B.

Feed restrictor for ESO/ESP [42A] + [45A]

To enable individual adaptation of the speed with which a function responds, a number of restrictors from ∅0.6 to ∅2.0 in diameter can be chosen. Common version: ∅1.0 mm.

Pump/tank connection for ESO/ESP on one section only [47]

RB1 Reducer valve - see [50] - mounted on spool section and turned toward the inlet section.

RB2 Reducer valve - see [50] - mounted on spool section and turned away from the inlet section.

RA1 Reducer valve - see [50] - mounted on spool section and turned toward the inlet section. The section also has connection threads for tank and external take-off of the reduced pump pressure. The connection threads are turned away from the inlet section.

RA2 Reducer valve - see [50] - mounted on spool section and turned away from the inlet section. The section also has connection threads for tank and external take-off of the reduced pump pressure. The connection threads are turned toward the inlet section.

G1 Threaded connection port on spool section for connection of pump and tank. Turned toward inlet section. Max. pump pressure: 35 bar.

G2 Threaded connection port on spool section for connection of pump and tank. Turned away from inlet section. Max. pump pressure: 35 bar.

GS1 Threaded connection port on spool section for connection of pump and tank. Turned toward inlet section. Max. pump pressure: 35 bar. The threaded connection contains a bleed-off restrictor (diam. 1.2 mm) between the pump and tank, so that warm oil will always circulate.

GS2 Threaded connection port on spool section for connection of pump and tank. Turned away from inlet section. Max. pump pressure: 35 bar. The threaded connection contains a bleed-off restrictor (diam. 1.2 mm) between the pump and tank, so that warm oil will always circulate.
Directional control valves

Pump/tank connection for ESO/ESP on more than one spool section. Section nearest inlet [48]

- **R**: Reducer valve fitted. See [50].
- **G**: Threaded connection port. Max. 35 bar pump pressure.
- **S**: No connection port or reducer.
- **SS**: Bleed-off restrictor (diam. 1.2 mm) between pump and tank for continuous circulation of warm oil.

Pump/tank connection for ESO/ESP on more than one spool section. Section furthest from inlet [49]

- **R**: Reducer valve fitted. See [50].
- **G**: Threaded connection port. Max. 35 bar pump pressure.
- **S**: No connection port or reducer.
- **SS**: Bleed-off restrictor (diam. 1.2 mm) between pump and tank for continuous circulation of warm oil.

Reducer valve for ESO/ESP spool actuator [50]

- **35**: Reducer valve fitted (for R, RB1, RB2, RA1 or RA2 above). Setting: 35 bar at flow of 0 l/min. Max. pressure in pump connection: 250 bar.

The graph shows the relationship between reduced pressure ($P_{red}$) and take-off flow ($q_{red}$) from the reducer valve. The formula:

$$P_{red} = \text{reduced pressure}$$

$$q_{red} = \text{take-off flow from reducer valve}$$
Choice of spool

The spool is the most important link between the actions of the operator and the movement of the controlled function. VOAC Hydraulics therefore goes to great lengths to optimize spools for different flows, load conditions, functions and applications. Since this is a process of continuous development work, new spools are being introduced all the time. For this reason, the many different spools available are not detailed in this catalogue. For assistance with the choice of spool, please contact your nearest VOAC representative.

Spool function

Spools are divided into different groups, depending on their basic function.

- **D** Double-acting spool for, e.g. double-acting cylinder. A and B ports blocked in the neutral position.
- **EA** Single-acting spool for, e.g. single-acting cylinder. A and B ports blocked in the neutral position and service port B blocked in all positions.
- **EB** Single-acting spool for, e.g. single-acting cylinder. A and B ports blocked in the neutral position and service port A blocked in all positions.
- **M** Double-acting spool for, e.g. hydraulic motor. Service ports A and B connected to tank (float position) in neutral.
- **F** Double-acting spool with fourth position in which both service ports are connected to tank (float position). A and B ports blocked in neutral position.
- **S** Double-acting spool for double-acting function. S spools are specially designed to handle light-load functions such as swing, rotator, etc.
- **CA** Regenerative spool for rapid feeding of a cylinder, or for flow saving. The large side of the cylinder is always connected to service port A.
- **DQA** Double-acting spool for, e.g. double-acting cylinder. A and B ports blocked in the neutral position. An integrated flow-limiting valve (lowering brake) limits the lowering speed (service port A to tank).

In addition to division into groups according to function, spools are grouped according to whether the spool end is open or closed. Spools with closed ends are used with the PC1, PC2, EHC1 and EHC2 spool actuators and have the letters PC incorporated into the spool designation, e.g. DPC, EPCA, MPC, SPC and CPCA. Spools with open spool end are used with all other spool actuators.

Spools with closed ends are designed in such a way that the flow forces can be exploited to give pressure-compensated flow control, i.e. when the load pressure changes, the flow to the service port remains almost unaffected. See page 5 for more information.

Spool designation

Each spool has an imprinted alphabetical code to facilitate identification during tuning or servicing in the field.

Flow limitation (lowering brake)

As stated above, the DQA spool is equipped with a flow-limiting valve between service port A and the tank gallery. This valve limits the maximum flow almost regardless of the load pressure.

The following standard settings are available: 40, 50, 60 and 70 l/min.
Options in the spool section

Options in the pump gallery [38]
The spool section’s pump gallery can be fitted with different accessories to give the best system construction.

- **X**: Without load-hold check valve.
- **X2**: Without load-hold check valve; section prepared for fitting of feed reducer (MR).
- **N**: Load-hold check valve to prevent undesirable sinking of the function. Common version.
- **MM**: Load-hold check valve equipped with gauge port for measuring of pump pressure. Connection thread: G1/4.
- **MS**: Load-hold check valve equipped with adjustment screw for restricting flow to consumer.
- **A64**: Same as MS, but with better resolution in adjustment range. Can only be used for limiting flows of up to 40 l/min. Max. permissible pump pressure: 280 bar.
- **MR**: Common feed reducer for service ports A and B fitted and factory-set at desired pressure level (20-220 bar). Set at a flow of 10 l/min. MR can be remote controlled via a relief valve in the pilot line (tank line). For F150CP only. Connection thread: G1/4.

The feed reducer is used to limit the pressure from the valve when the maximum pressure of the section is below that of the main pressure relief valve, e.g. for a clamping function. By using MR as a pressure limiter, energy losses can be kept down, since MR only consumes a pilot flow. The pressure setting should be as close as possible to, but at least 20 bar lower than, the value set on the port relief valve.

---

**Graphs**

- **P<sub>red</sub> (bar)**: Reduced pressure in service port
- **q<sub>m</sub> (l/min)**: Flow out of service port

P<sub>red</sub> = reduced pressure in service port  
q<sub>m</sub> = flow out of service port
Directional control valves
Series F

Pressure limiters in service ports
(Port relief valves) [40]-[44]
The service ports can be equipped with individual port-relief and/or anti-cavitation valves.
VOAC PLC082 cartridge valves are used as port relief valves. They are renowned for their long service life, tightness, fast opening sequence and good characteristics over the entire flow range.

Port relief valve [40] and [43]
X1 No port relief valve fitted. Service port connected to valve’s tank connection.
X2 No port relief valve fitted. Service port connected to valve’s tank connection. Hole plugged with plastic plug. Selected when port relief valve not required. Port relief valve or steel plug must, however, be fitted before valve can be used.
Y No port-relief or anti-cavitation valve fitted. Connection between service port and tank gallery blocked.
PA PLC082 combined port-relief and anti-cavitation valve fitted. Valve is factory-set.
N Only anti-cavitation valve fitted.
A26 PLC082 adjustable port relief valve fitted. No anti-cavitation function. Valve is delivered preset at desired value (max. 280 bar). It is then adjustable within selected interval. Following intervals are available: 25-62, 63-99, 100-139, 140-174, 175-209, 210-249 and 250-280 bar.
A46 Port relief valve with integrated sequence-valve function, i.e. port relief valve is force-opened when the preset pressure is reached in the sequence-valve connection, regardless of the pressure in the service port. The opening pressure of the sequence valve can be set anywhere from 30% below to 125 bar above the pressure setting on the port relief valve. A46 is delivered factory-set at the desired pressure level. With A46, the anti-cavitation function of the port relief valve is limited.
Connection thread: G1/4.

Pressure setting [41]-[44]
Max. 280 bar for valves in grey-iron version.
Max. 350 bar for valves in nodular-iron version.

\[ \Delta p \text{ (bar)} \] Anti-cavitation characteristics

\[ \Delta p \text{ (bar)} \] Port relief valve characteristics

In the circuit diagram above, section 1, service port A, is equipped with a combined port-relief and anti-cavitation valve (1) to limit the pressure and prevent cavitation. Section 1, service port B, is fitted with a Y-plug (2) to block the connection to tank. Section 2, service port A, is connected to tank (3) in the case of EB spoils. Section 2, service port B, is fitted with an anti-cavitation valve (4).

A46 - integrated sequence valve for load-moment limitation. When the opening pressure of the sequence valve is lower than that of the port relief valve, external drainage to tank is added as shown in the illustration above.
Function blocks

Series F valves can be equipped with manifold-type function blocks that enable total system solutions to be integrated into the valve.

Standardized function blocks are available for, e.g. common feed reducer in F150CP (A60).

Please contact your VOAC representative for more information about total system solutions. In addition to standardized function blocks, our experienced product and system designers can adapt function blocks to meet your needs in full.

The function block above was specially adapted for a customer. Like most function blocks, it was built up using cartridge valves. Only the housing itself is a unique component.

Hand levers

Hand levers are not supplied with Series F valves and must therefore be ordered separately.

The standard levers for Series F valves are of steel and are surface treated to give resistance to corrosion. Lever knobs are of black plastic and available in either plain-ball or "window" versions.

In the window version, machine builders can insert the desired function symbol beneath a transparent cap.

Levers are supplied complete with pin kits for mounting to the directional valve.

<table>
<thead>
<tr>
<th>Lever:</th>
<th>Ordering No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>M9 (Window knob)</td>
<td>9126 1809-01</td>
</tr>
<tr>
<td>M92 (Ball)</td>
<td>9126 2592-01</td>
</tr>
<tr>
<td>M91 (Window knob)</td>
<td>9126 2052-01</td>
</tr>
<tr>
<td>M94 (Ball)</td>
<td>9126 3860-55</td>
</tr>
<tr>
<td>M96 (Coordinate lever [joystick] for two sections with ball)</td>
<td>3763809</td>
</tr>
</tbody>
</table>
Directional control valves

Dimensional drawings (spool actuators)

C

B3

CB

TPOL

DPOL

DTPOL

LU

LM

Spool stroke 6.5 mm (0.26 in) opens “pump to service port A”

Spool stroke 13.5 mm (0.53 in) for spool function F [32], others 6.5 mm (0.26 in) open “pump to service port B”
Dimensional drawings (spool actuators)
Directional control valves

Series F

Dimensional drawings

For the pump-unloading inlet section above and mid-inlet section below, only the dimensions that differ from those of the standard inlet section have been given.

<table>
<thead>
<tr>
<th>No. of sections</th>
<th>L with end section mm</th>
<th>L with spool/ outlet section mm</th>
<th>L with end section in</th>
<th>L with spool/ outlet section in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>152</td>
<td>144</td>
<td>5.98</td>
<td>5.67</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>192</td>
<td>7.87</td>
<td>7.56</td>
</tr>
<tr>
<td>3</td>
<td>248</td>
<td>240</td>
<td>9.76</td>
<td>9.45</td>
</tr>
<tr>
<td>4</td>
<td>296</td>
<td>288</td>
<td>11.65</td>
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<td>5</td>
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<td>336</td>
<td>13.54</td>
<td>13.23</td>
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<td>384</td>
<td>15.43</td>
<td>15.12</td>
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<tr>
<td>7</td>
<td>440</td>
<td>432</td>
<td>17.32</td>
<td>17.01</td>
</tr>
<tr>
<td>8</td>
<td>488</td>
<td>480</td>
<td>19.21</td>
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</tr>
<tr>
<td>9</td>
<td>536</td>
<td>528</td>
<td>21.10</td>
<td>20.79</td>
</tr>
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<td>10</td>
<td>584</td>
<td>576</td>
<td>22.99</td>
<td>22.68</td>
</tr>
<tr>
<td>11</td>
<td>632</td>
<td>624</td>
<td>24.88</td>
<td>24.57</td>
</tr>
</tbody>
</table>
For further information, please contact: