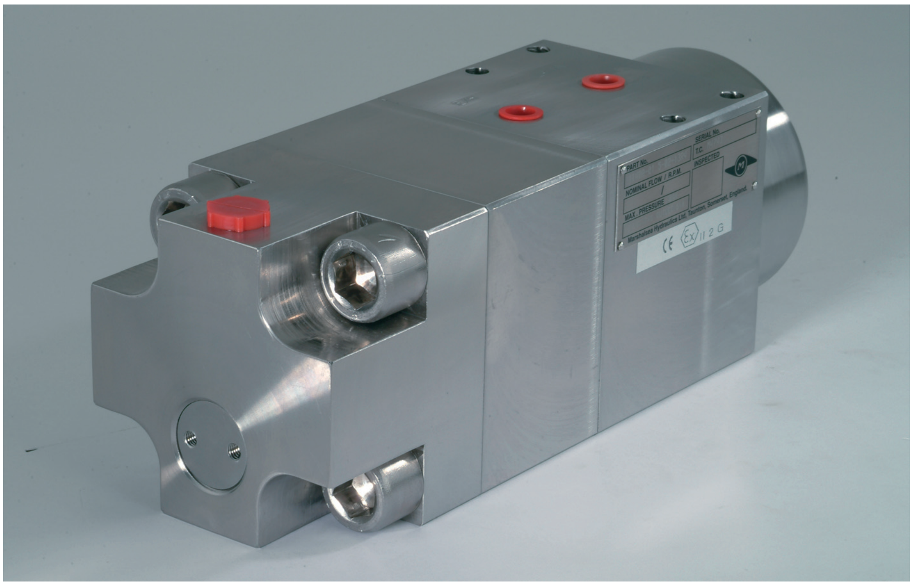
MARSHALSEA HYDRAULICS

ESTABLISHED · 1830

HI 11400 Pressure Intensifier (subsea model)



- Designed to boost any water-based or mineral/synthetic oil-based fluid.
- Boosts inlet pressure up to 10 times without external power.
- When system pressure is achieved, no consumption of expensive hydraulic fluid. Maximum outlet 1,500 bars.
- Manufactured from 316 (standard), or from duplex stainless steels; – no painting required for hostile environments.
- Costs reduced – no electrical supply or controls required.
- Production quality to the stringent standards required for hostile subsea environments.
- Two versions – with and without a pilot-operated vent valve for the high pressure line.

CE Ex II 2 G

This pressure intensifier conforms to Directive 94/9/EC relating to equipment intended for use in potentially explosive atmospheres and is ATEX (AT*mosphere* EX*plosible*) certified.

SYSTEM CERTIFICATION ISO 9001:2000 SGS

UKAS QUALITY MANAGEMENT 005

Marshalsea Hydraulics has been assessed by SGS Société Générale de Surveillance SA and certified as meeting the requirements of ISO 9001:2000 for the design, development, manufacture and servicing of hydraulic pumps, relief valves and intensifiers.

General description

The HI 11400 subsea pressure intensifier amplifies the inlet pressure to a higher outlet pressure by a predetermined ratio. Standard ratios are shown in the table below; special ratios are available on request.

Pressure in the high pressure line can become reduced as a result of a system leak or the use of the stored (pressure) energy. Using virtually no energy, the HI 11400 restores and maintains that pressure in such instances. Rapid adjustment of the high pressure line can be achieved by varying the inlet pressure as the high pressure is directly proportional to the inlet pressure. Check and changeover valves are integrated within the main body of the intensifier as is the pilot-operated vent valve in the 11400–xx–02 version. When *the inlet pressure* x *the ratio* = *the outlet pressure*, then the HI 11400 is in a stalled condition and there is no consumption of fluid. The maximum outlet pressure that can be offered is currently 1,500 bars.

Applications

The HI 11400 was designed for subsea applications in the offshore oil and gas industry where the highest standards of product performance and durability are essential. The HI 11400 is manufactured from 316 stainless steel to withstand hostile environments; it can operate on all water-based glycol fluids or on mineral and synthetic oils. This product is ideal for charging accumulators from a low pressure umbilical; it may also be used for operating several different systems from a single supply.

Product selection

The *required ratio* = *required high pressure* / *inlet pumped or regulated pressure*. Available ratios can be selected from the table below. Ensure that the inlet pressure does not exceed the pressure given in this table which also offers a guide to approximate charging flow rates in litres/min.

Product number	Ratio	Maximum inlet pressure (bars)	HP piston swept volume (cc)	Flow at 1 stroke/sec (l/m)
11400–02	**2:1**	345	36.37	2.18
11400–H2	**2.5:1**	345	26.00	1.56
11400–03	**3:1**	345	24.22	1.45
11400–04	**4:1**	345	18.17	1.10
11400–05	**5:1**	300	14.54	0.87
11400–06	**6:1**	250	12.11	0.73
11400–07	**7:1**	215	10.36	0.62
11400–08	**8:1**	185	9.06	0.54
11400–09	**9:1**	165	8.06	0.48
11400–10	**10:1**	150	7.25	0.44

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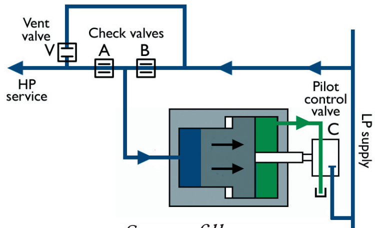
These basic product numbers **(BPN)** can be extended to accommodate additional options as indicated in the following table.

Product number	Inlet connection	Outlet connection
Model without pilot-operated vent valve		
BPN–01–11	1/4” NPT	1/4” NPT
BPN–01–12	1/4” NPT	1/4” BSP
BPN–01–13	1/4” NPT	3/8” MP Butech
BPN–01–21	1/4” BSP	1/4” NPT
BPN–01–22	1/4” BSP	1/4” BSP
BPN–01–23	1/4” BSP	3/8” MP Butech
Model which includes pilot-operated vent valve		
BPN–02–11	1/4” NPT	1/4” NPT
BPN–02–12	1/4” NPT	1/4” BSP
BPN–02–13	1/4” NPT	3/8” MP Butech
BPN–02–21	1/4” BSP	1/4” NPT
BPN–02–22	1/4” BSP	1/4” BSP
BPN–02–23	1/4” BSP	3/8” MP Butech

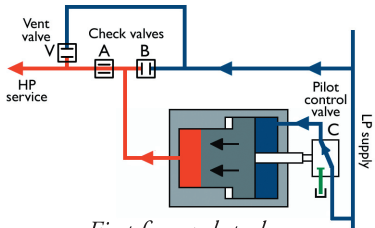
Method of operation

On startup the system fills from the low pressure (LP) supply line. The LP pressure on the left of the piston pushes it to the right against the zero pressure tank fluid. When it reaches the end of its travel, the pilot control valve C reverses.



System fill

The LP supply fluid can now invade the right hand end of the cylinder where the piston’s surface area is larger than at the HP end. The greater force (pressure x area) pushes the piston to the left on its first forward stroke. The increased pressure generated at the HP end closes check valve **B** and is the first step in building the pressure in the HP service line.



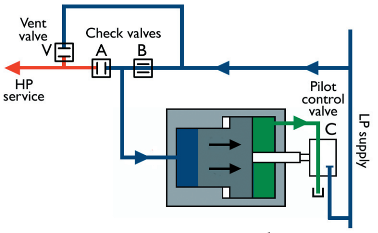
First forward stroke

Subsequent forward and reverse strokes are shown below. With valve **A** open and valve **B** closed the piston moves forward to inject fluid into the HP service line. For the reverse stroke valve **B** is open and valve **A** closed..

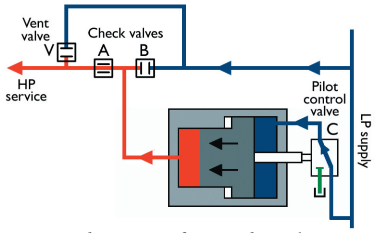
On these diagrams:
Red = high pressure
Blue = low pressure
Green = exhausted fluid

The intensifier typically becomes stalled in the forward stroke position with *the LP inlet pressure* x *the ratio* = *the HP outlet pressure*. In this situation there is no consumption of hydraulic fluid with both pistons in a static state with pressure locked between the valves **A** and **B**. The device can sit indefinitely in this position . . . but the instant there is a drop in the HP pressure line, the piston moves further forward to recover the desired pressure.

On these diagrams:
Red = high pressure
Blue = low pressure
Green = exhausted fluid

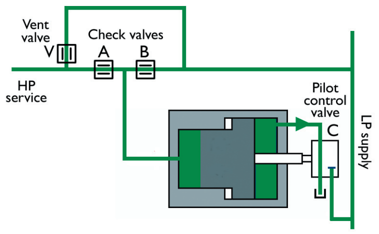


Reverse stroke



Subsequent forward strokes

The pilot-operated vent valve shown as **V** in these diagrams is included on the HI 11400–xx–02 models but omitted in the HI 11400–xx–01 models. With the HI 11400–xx–02, if for any reason the low pressure supply is interrupted, the system floods with zero pressure "tank" fluid. In such a circumstance, the pilot-operated vent valve **V** is no longer held closed by the input pressure – it opens so that the high pressure is safely vented away.



Material

Manufactured from 316 stainless steel with nitrile seals. Weight 11 kgs (HI 11400–xx–01 model) or 26 kgs (HI 11400–xx–02 models) .

Fluids

Suitable for use with mineral/synthetic oils and all water-based fluids such as HW540, HW443 and Tranaqua HT, plus many others. The fluids used should be to a cleanliness standard of NAS 1638 class 6.

Mounting

The pressure intensifier can be mounted vertically or horizontally.

Custom versions

Customised versions can be produced with customer specified connections and mounting.

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System temperature

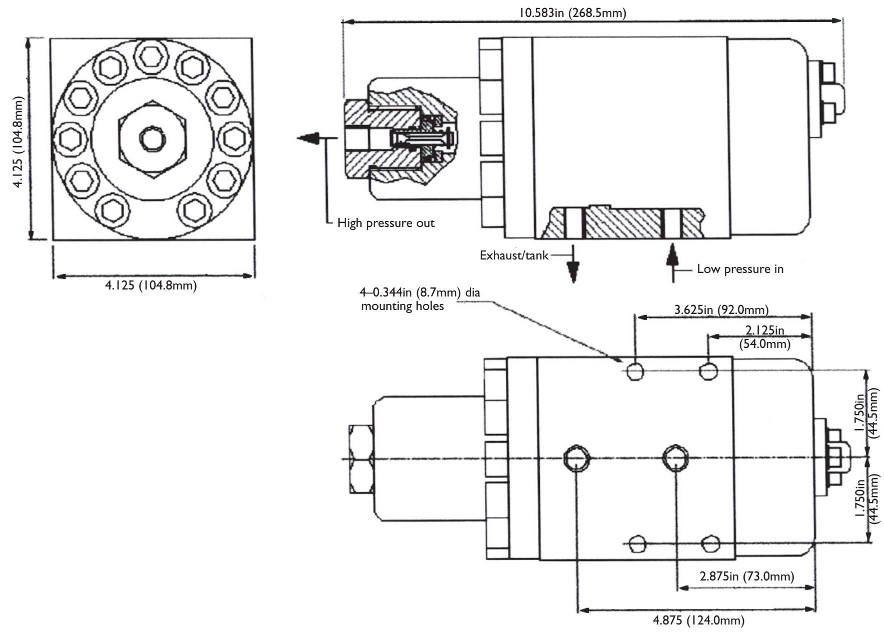
The HI 11400 has been qualified to operate at temperatures from –10°C to +80°C at pressures up to a maximum of 1,500 bars.

Safety note

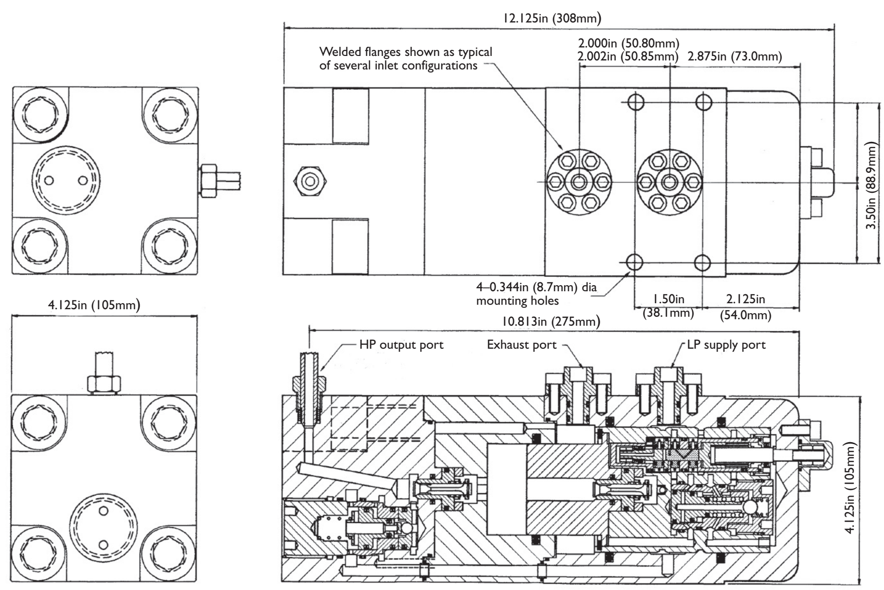
The inlet pressure of the intensifier should be carefully controlled, as the outlet pressure increases by the ratio of the pump in use. For example, if an 8:1 intensifier is being used, a rise in the inlet pressure of 125 bars will immediately increase the outlet pressure by 1,000 bars.

A relief valve set at the maximum pump rating should be fitted immediately downstream of the pump delivery port.

HI 11400–xx–01 drawing giving dimensions



HI 11400–xx–02 drawing giving dimensions



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HI 11400 Qualification Testing

It is recognised that reliability and consistent performance are critical in subsea operations where the cost of failure can be extremely high. The operational benefits which the HI 11400 can provide are significant and attractive (see page G010). For this reason, Marshalsea Hydraulics and various client companies have run a number of qualification trials of this innovative product. The following summarises trials that have taken place:

External Testing (Wormald) 8 to 1 ratio intensifier, discharge pressure 1,250 bars mineral oil @ 80 deg C (artificially heated), total number of cycles 4,000. Application: topside high temperature/pressure wells. Projects: Shearwater/Elgin Frankling/Sable.

Internal Testing 5 to 1 ratio intensifier, discharge pressure 1,500 bars; water glycol *Transaqua HT* at 20°C; total number of cycles 174,000. Application: subsea.

Internal life Test 5 to 1 ratio intensifier, discharge pressure 1,500 bars; water glycol *Transaqua HT* at 20°C; total number of cycles 500,000. Application: subsea, sea water washed. Project: Shell/Cook/Kvaerner.

Internal life Test 5 to 1 ratio Intensifier, discharge pressure 1,000 bars; water glycol *Transaqua HT* at 20°C; total number of cycles 526,000. Application: subsea.

Internal life Test 2.5 to 1 intensifier, discharge pressure 950 bar; water glycol *HW443* at 20°C; total number of cycles 100,000. Application: subsea control module mounted (dual redundant module), Project: Vigdis/Norsk Hydro/FMC Kongsberg. **See page G011 for the published conclusions of this test.**

Internal life Test 3 to 1 intensifier, discharge pressure 1035 bars; water glycol *HW740R* at 20°C; total number of cycles 750,000. Application: subsea control module mounted (dual redundant intensifiers). Project: Rhum BP/ABB Offshore. **See page G012 for the published conclusions of this test.**

External Testing (READ) 8 to 1 down hole intensifier (less than 4 in/100mm in diameter); discharge pressure 22,500 psig of water glycol. Application: subsea swaging of casing tube.

Cost savings

Reduce number of umbilical lines

Simplification of Control Module (no HP rated components)

Development of fields with different well bore shut in pressures at each well without additional HP umbilical lines from topsides.

Avoidance of very high pressure lines on topside installation, in risers and subsea.

New development opportunities

Allows high pressure developments to be tied back to existing subsea infrastructure, with lower rated HP pressure infrastructures.

Mitigation for damaged/old umbilicals – derating, providing reduced OPEX/extended field life for existing infrastructures

Selection of downhole valve not dependent on HP pressure and position in wellbore

Development of fields where required HP pressure is in excess of current reliable umbilical technology.

Reliability

Reduce number of moving parts

Based on proven, reliable technology (300 topside operational units)

Reduced number of subsea connections

Enhanced safety

Avoidance of very high pressure lines on topside installation, in risers and subsea.

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RESULTS OF CYCLING TESTS

The cycling tests are designed to monitor the forward to return stroke transition of the test intensifier and any deterioration in leakage rates.

The graphs of HP and LP taken at 25,000 cycle intervals show the transition from forward stroke to reverse stroke as indicated by the drop in the supply pressure (the first of these graphs is marked with the return stroke duration). The unit was set to travel forward at the slowest possible speed by setting the smallest achievable leak from the HP control valve (PV2), at the point of return stroke a screen capture was taken showing the condition of the HP and LP and the duration of the return stroke. The depression in the lower trace is the drop in supply pressure caused by the ~ return stroke of the intensifier, this is used to mark the start and fmish points of the return stroke. The graphs show that during the return stroke there is no falloff in HP indicating zero or near zero leakage across the HP piston seal and primary check valve. The traces shows rapid transition from forward to return stroke with no dead band and associated fall in HP, this provided clear evidence that the hydraulic over center mechanism is functioning correctly and has not deteriorated. There has been no observable change in performance over the 100,000 cycles.

Leakage rates to exhaust and HP to LP interflow have shown an increase during the test from O.Ollcc/min and 0.003cc/min respectively to 0.020cc/min and 0.008cc/min. Readings taken prior to the contamination test of 0.015cc/min and 0.005cc/min show a reversal of this trend. Fractional changes in the supply pressure have a marked effect on the position of the LP piston which is used to determine true leakage rates and with such very small movements and leakage a degree of drift is to be expected. As with all hydraulic equipment containing valves and seats deterioration will take place during the life of the unit but as the intensifier is expected to be moving slowly in service the measured leakage expressed as a fraction of the consumed fluid is very small.

RESULTS OF HYPERBARIC CHAMBER TEST

The test intensifier was subjected to a series of pressure regimes while contained in a hyperbaric chamber. Inlet and hyperbaric pressures were varied across a prescribed band and the resulting effects plotted in graph form. The test was to simulate the effect of an intensifier being deployed sub sea with the supply line, exhaust line and HP outlet being effectively returning to the surface. The graphs clearly show the result of varying either of the pressure parameters and that the results can be accurately predicted. Providing the inlet, exhaust and HP outlet see the same depth pressure an intensifier can be deployed at any water depth with no loss of function.

RESULTS OF CONTAMINATION TEST

The complete test rig and associated pipework was deliberately contaminated to class lOB to determine the test intensifier resistance to fluid contamination. Pall Machinery were commissioned to provide the technical support necessary to contaminate the system to a specific level and provide constant on line cleanliness monitoring during the test. The test intensifier's performance and system cleanliness (5B/6B) was logged prior to any changes being made to the hydraulic system and the data recorded. All three filters were removed and the system rechecked (8B/9B) ISO medium test dust was added until the required contamination level was reached and 5,000 cycles was initiated. The intensifiers performance was logged on completion of 5,000 cycles and the data recorded. Comparison of the performance figures prior and post test show the ~ test intensifier to be unaffected by this level of contamination, it is clear that much higher levels of contamination will be required before any change in performance becomes evident. The performance figures recorded were witnessed by a representative of Pall Machinery.

RESULTS OF PROOF PRESSURE TEST

The results from this test are self-evidently satisfactory.

DETERMINATION OF OUTPUT PRESSURE BAND

The purpose of this test is to establish the percentage loss in output pressure due to the internal seal friction and manufacturing tolerances. The results of measurements and calculations indicate ~ an expected loss of 1.6% on the theoretical output pressure due to friction. When this figure is applied to the manufacturing tolerances an overall output pressure tolerance band of -1.5 to -1.7 % is determined. At the outset of the cycling test it was observed that the output pressure was marginally lower than at the completion of the test due to a higher frictional loss. During a period of cycling internal polishing takes place reducing the frictional loss with a subsequent rise in output pressure. In view of this it is prudent to use a loss figure of -2.0 % when calculating pressures.

DETERMINATION OF VENT VALVE RELEASE POINT

A series of tests were performed to establish the point at which the vent valve releases while discharging the supply pressure. Although this test was carried out during the cycling tests the results are not considered sufficiently accurate for detailed analysis. The tests were repeated with the HP discharging from pressures of 950 bar to 500 bar in 100 bar increments and the results plotted in graph form. The graph traces indicate that the point at which the vent valve releases is dependant upon the level of HP being vented. The higher the HP the higher the vent valve release pressure. This is simply a function of loads, pressures and areas. The pressure at which the valve releases is not a precise value, small variations will be present due to changing frictional values with different process fluids and variations in manufactured parts.

QUALIFICATION TEST FOR ABB OFFSHORE SYSTEMS – CONCLUSIONS

DATA LOGGER SCOPE TRACES

The graphs of HP and LP taken at intervals through out the test show the transition from forward stroke to reverse stroke as indicated by the drop in the supply pressure (the first of these graphs is marked with the return stroke duration). The unit was set to travel forward at the slowest possible speed by setting the smallest achievable leak from the HP control valve (PV2), at the point of return stroke a screen capture was taken showing the condition of the HP and LP and the duration of the return stroke. The depression in the lower trace is the drop in supply pressure caused by the return stroke of the intensifier, this is used to mark the start and finish points of the return stroke.

The graphs show that during the return stroke there is no fall off in HP indicating zero or near zero leakage across the HP piston seal and primary check valve. The traces shows rapid transition from forward to return stroke with no dead band and associated fall in HP, this provided clear evidence that the hydraulic over center mechanism is functioning correctly and has not deteriorated. There has been no observable change in performance over the 700,000 cycle duration of this test.

LEAKAGE TO EXHAUST AND LP PISTON FORWARD MOVEMENT

The purpose of recording the total leakage to exhaust and the forward movement of the LP piston is to distinguish between the discharged/displaced fluid which derives from the normal operation of the intensifier and leakage across the various internal valves. Fluid from both these sources is discharged into the exhaust line. During the course of the test the measured leakage from the exhaust has increased from one drip (0.045cc) in 5 minutes to 2 drips (0.09cc) in 5 minutes and the forward movement of the LP piston has increased from 0.006mm to 0.012mm. These measurements are so small as to be insignificant, Marshalsea acceptance for an FAT on an intensifier is 0.20cc in 5 minutes and this is considered to be a low value.

Fractional changes in the supply pressure have a marked effect on the position of the LP piston which is used to determine true leakage rates and with such very small movements and leakage a degree of drift is to be expected. As with all hydraulic equipment containing valves and seats deterioration will take place during the life of the unit but as the intensifier is expected to be moving slowly in service the measured leakage expressed as a fraction of the consumed fluid is very small

OUTPUT PRESSURE

The measurements taken of output pressure show a variation of 4 bars (1025 bars-1029 bars) spread over the 14 test points. This would indicate a variation in supply pressure better than 1.5 bars due to the 3:1 multiplication from LP to HP. The nominal calculated output pressure is 1035 bars, the measured output pressure of 1025 bars is 1 % low compared with the calculated figure. A loss between 1 % and 2 % in normal for all intensifiers and is a result of internal friction and /or manufacturing tolerances..

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