The Sprayer Textbook

An explanation of components on broad-acre field sprayers
to help in the service and support of HARDI sprayers

HARDI

The Sprayer

The Sprayer Textbook

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Printed in Denmark
First published March 2016

HARDI reference number 89278000

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Conversions

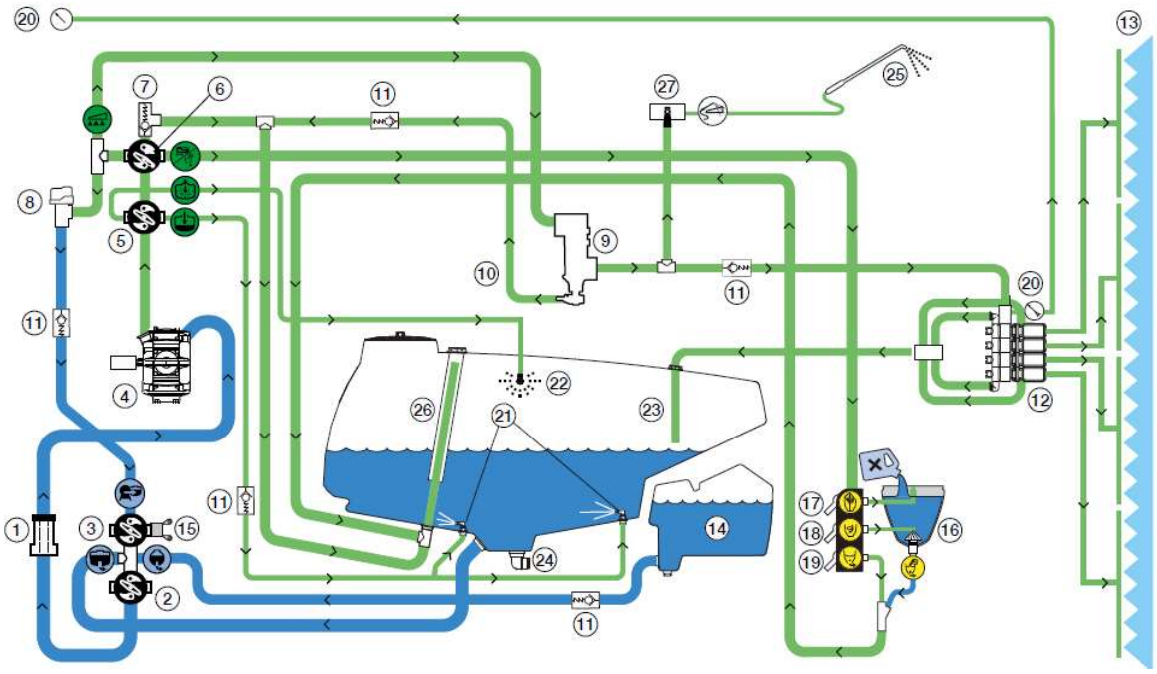
1.0 metre	39.37 inches
1.0 km	0.621 miles
1.0 litre	0.264 US gallons
1.0 hectare	2.471 ac
1.0 bar	14.5 psi
1.0 kilogram	2.205 pounds
1 litre/ha	0.107 US gallon/ac
1 Newton metre	0.74 lbft
20° Celsius	68° Fahrenheit
Celsius	Fahrenheit (°C x 1.8) + 32

Note
Left and right references are made in facing the direction of travel

Contents

Introduction

Liquid function diagram for the HARDI RANGER sprayer from 2014



Foreword

Dear Reader,

Most people are fascinated by modern agricultural sprayers. The huge size and automation of nearly everything is truly remarkable and almost incredible if we go self-steering, self-propelled sprayers.

Strangely enough, the basic composition of a sprayer has not changed much over the last 60 years. It still comprises of a pump, controls, tank, frame, filtration and nozzles. The components have been refined but not the composition.

You are probably about to read this book because you are involved with service and support for the HARDI customer. This book is written to give you a basic understanding of the HARDI sprayers. It is divided into chapters that will guide you through the sprayer, component by component that, in the end, will help you understand the complete sprayer.

The chapters follow the divisions of the HARDI parts catalogue and start with pumps as the pump is the “heart” of the sprayer. This textbook also includes nozzle basics as the nozzle is the deciding component, the “brain” if you like, for spray quality before the liquid leaves the sprayer.

The chapters may also contain some historical content as an aid to help you understand the present products.

A chapter on the principles of fault-finding technique is also included. This will hopefully minimise your on-farm time and maximise the customer satisfaction.

The final chapter addresses identification of the HARDI sprayers. It includes part number logic, symbols and identification of older models. The model identification might be of help in finding the correct parts for these older models.

This book mainly addresses broad-acre field sprayers although vineyard and orchard sprayers are mentioned.

It is also used as background material for the HARDI basic training courses and in conjunction with a slide series used on these courses.

The HARDI world started in 1957. We make sprayers from the ground up and know nothing else but sprayers and spraying. This makes us both sprayer specialists and the best ally a customer can have and vulnerable should we not live up to customer expectations. It forces us to be pioneers in the world of agricultural application techniques and machinery and we enjoy this challenge.

We hope you also enjoy the challenge and welcome you to our HARDI world.

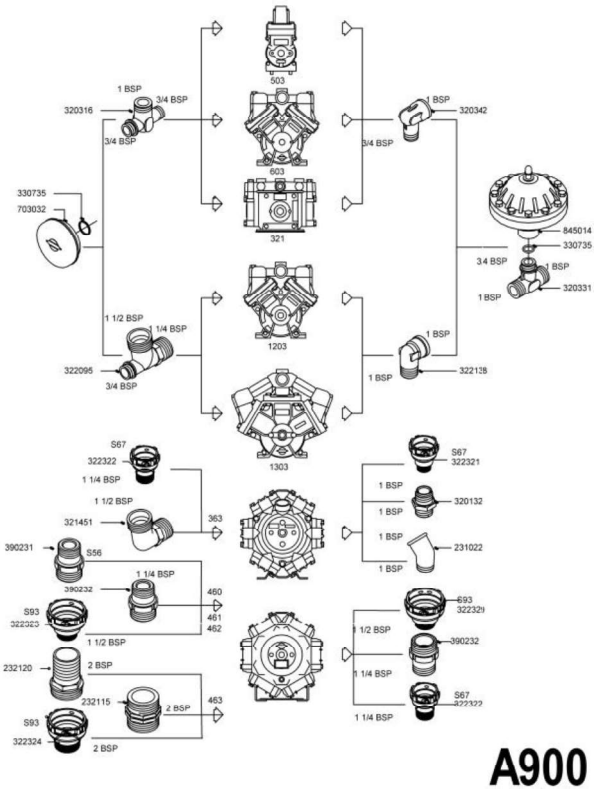
About the author

Anthony Facchin was born in 1956 in Horsham, a country town in the middle of an Australian farming community. After completing studies in agriculture, Anthony Facchin worked on Australian, Canadian and Danish farms and then settled into an Australian business supplying agricultural pesticides and spray equipment. With a flair for technique, he started a 2-year apprenticeship with HARDI in Denmark, and after this he returned to Australia to work for a HARDI importer.

In 1985, Anthony returned to HARDI in Denmark where he worked in Technical Service, Product Management, Export and After Market. In 2010, Anthony was appointed manager for HARDI Academy in Denmark for the Global Marketing Group.

Pumps

Basic models



Range and Identification

The HARDI company is founded on the diaphragm pump and started the business in 1957. The concept of a simple, robust pump with dry sump and cast iron crankcase and covers has not changed. There are now 7 basic models. The above diagram is from the A900 pages of the HARDI Parts Catalogue (EPC).

Model base names are 500, 600, 320, 1200, 1300, 360 and 460.
With updates, the last digit has changed, e.g. model 500 is now called model 503.

The pumps only have 1, 2, 3, or 6 diaphragms or diaphragm covers.

- 1 for 500-503 model pumps
- 2 for 600-603, 320-321 and 1200-1203 model pumps.
- 3 for 1300-1303 model pumps.
- 6 for 361-364 and 460-464 model pumps.

The older series of pumps, models 500, 600, 1200, 1202, 1300, 1301 and 1302 have imperial thread. The newer series of pumps which include 503, 603, 1203 and 1303 are metric. They are recognized in the naming of the pump ending with “03”. The liquid connections are always British Standard Pipe (BSP) inch thread. The pump capacity between old and new has not changed but all parts related to the thread and bolt sizes will have new reference numbers.

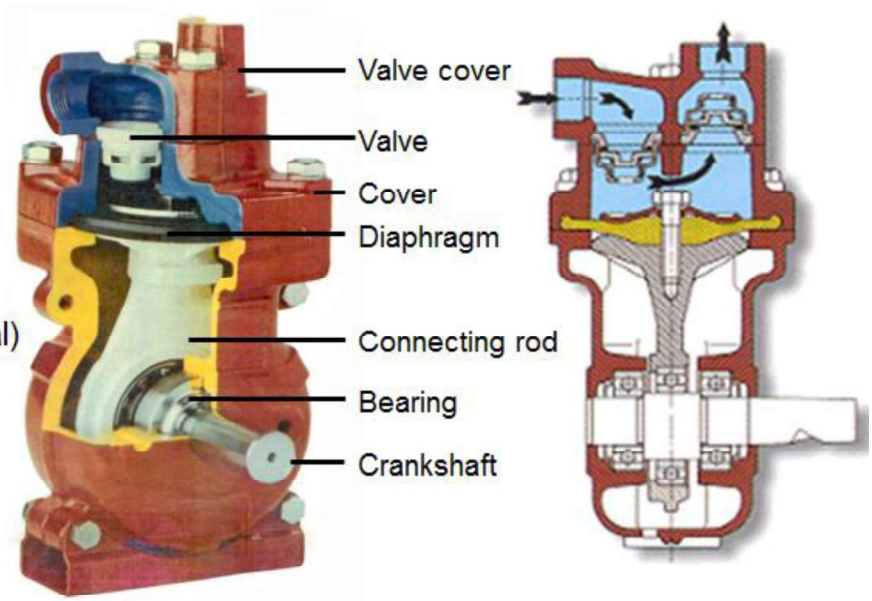
Pumps

Versions

Model variants

E.g., Model 503

Variants:
- Stroke
- Revolutions
- Crankshaft type
- Diaphragm (material)

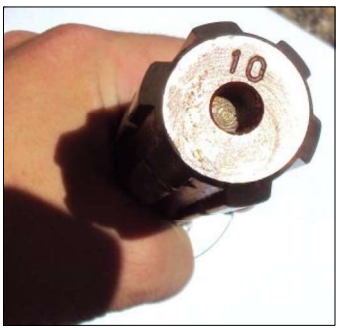


Stroke and revolutions

Models have different versions e.g.:
- Crankshaft type
- Diaphragm (material)

Stroke

Usually it is stamped on the crankshaft. Pumps with 3, 4, 5 or 6 mm strokes are typically for 1000 r/min applications. Pumps with 7, 9, 10 or 12 mm strokes are typically for 540 r/min applications.



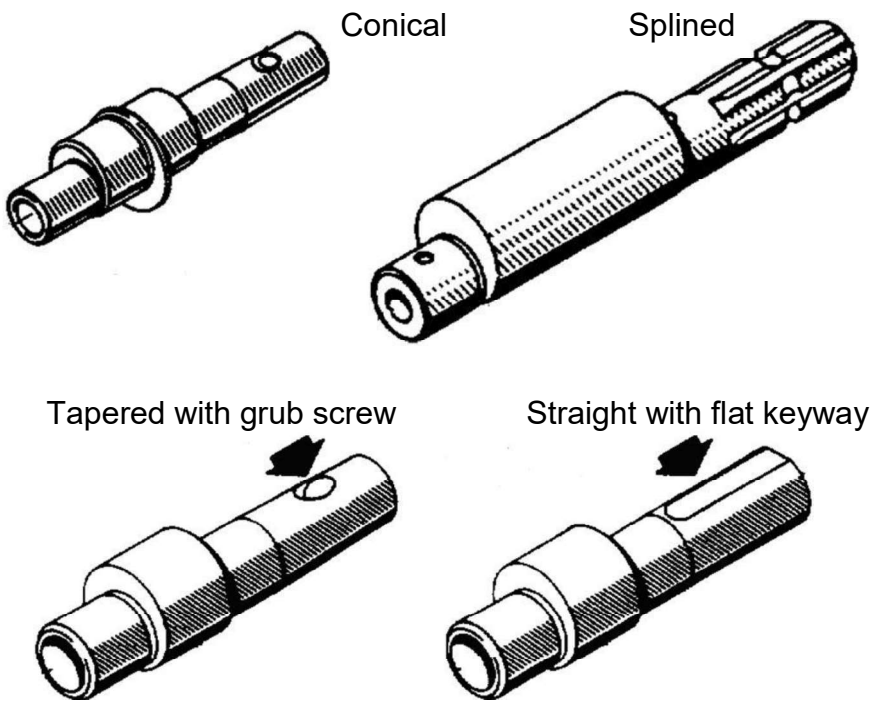
Revolutions

The rule is the higher the r/min, the shorter the stroke. This maintains the same capacity but reduces mechanical damage to the diaphragms. Conical shafts are usually on 540 r/min pumps. Note that it is not necessary to operate the pump at 540 r/min if the pump capacity is not required for the particular task.

Pumps with 6 spline crankshafts are for 540 r/min and those with 21 splines are for 1000 r/min.

Pumps

Crank and transmission shaft



Crankshaft and transmission shaft

Crankshaft type

Conical, splined and straight shafts are used.

- Conical (or tapered) shafts are used on the 1, 2 and 3 diaphragm pumps.
- Splined shafts are on the 6 diaphragm pumps and on some Model 321 pumps.
- Cylindrical (straight) shafts are used on the 1, 2 and 3 diaphragm pumps which are usually powered by a stationary electrical or combustion engine.

Some pumps have through-going crankshafts to power auxiliary equipment like a hydraulic pump.

Tractor power take-off (PTO)

The PTO usually supplies the mechanical power to the sprayer and is connected to the sprayer with a transmission shaft. The spline type may vary. The standard 540 r/min shaft has 6 splines and is $1^{3}/_{8}$" in diameter. Newer types for higher revolutions and power applications are found on larger tractors. A 21 spline $1^{3}/_{8}$" diameter transmission shaft is also available. Some Soviet and Chinese tractors have 8 splined shafts that rotate at 540 or 720 r/min.

Splined HARDI transmission shafts are available in 6 or 8 spline for 540 PTO r/min and 21spline 1000 PTO r/min. If a PTO drive is not available or desired, the pump can be hydraulically driven.

Pumps

Synthetic materials

Diaphragms

Diaphragm and O-ring material

Historically many materials were available for diaphragms. Today, there are basically 2 versions, polyurethane (PUR) or Nitrile.

O-rings requiring a high resistance to pesticides are supplied in a material called Viton.

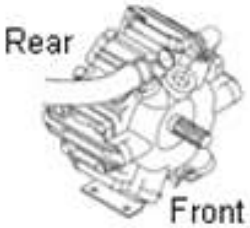
Material	Usage	Colour	Advantage	Disadvantage
Polyurethane	Standard for diaphragms Some O-rings	Yellow	Good all round value Low cost	Poor UV resistance
Nitrile	Option for diaphragms Some O-rings	Black	Good mechanical resistance Good heat resistance Low cost	Poor chemical resistance with alkaline and petro-chemical liquid
Viton ® (Registered trade name of DuPont)	O-rings	Green, brown matt black	High chemical resistance	Low mechanical resistance High cost

Pumps

Syntax for pump description

1 2 3 4 5 6 7 8

464 / 12.0 - 322 / 540 - 15 bar- S - 2 / 1¼ + notes



1. Model
2. Stroke in millimetres
3. Capacity in l/min at 0 bar and normal r/min
4. Normal working r/min
5. Maximum pressure in bar
6. Crankshaft type: S for Spline C for Conical Y for Cylindrical
7. Inlet/outlet in inches
8. Notes

Syntax of pump description

The pump identification follows a set syntax.

1. Model
2. Stroke (in mm)
3. Capacity in litre/minute at 0 bar and at normal nominated revolutions
4. Normal working revolutions (although the pump can operate at lower revolutions)
5. Maximum pressure in bar
6. Crankshaft type, being either, spline, conical or cylindrical
7. Inlet and outlet thread dimensions in inches
8. Notes, e.g. whether the pump is for hot liquids

Pump specification for 1303/6.0

1303/6.0	r/min	300		400		500		540		600		700		800		900		1000		1100		1200	
	bar	l/min	kW	l/min	kW	l/min	kW			l/min	kW	l/min	kW	l/min	kW	l/min	kW	l/min	kW	l/min	kW	l/min	kW
	0	41	0.9	54	1.2	70	1.5			82	1.8	94	2.1	106	2.4	122	2.6	136	3.0	151	3.3	165	3.6
	2	38	0.9	51	1.2	64	1.5			75	1.8	86	2.1	98	2.4	109	2.7	122	3.0	134	3.3	146	3.6
	4	37	1.0	49	1.3	62	1.6			73	1.9	83	2.2	94	2.4	104	2.7	116	3.1	130	3.3	138	3.6
	6	36	1.0	48	1.3	60	1.6			70	2.0	81	2.3	91	2.7	101	3.0	113	3.3	124	3.6	133	4.1
	10	34	1.1	46	1.4	57	1.8			67	2.2	77	2.6	87	3.0	97	3.3	108	3.7	117	4.1	128	4.6
	15	33	1.4	44	1.7	54	2.2			64	2.7	73	3.1	82	3.6	92	4.1	103	4.5	113	4.9	123	5.3
	PSI	gpm	Hp	gpm	Hp	gpm	Hp			gpm	Hp	gpm	Hp	gpm	Hp	gpm	Hp	gpm	Hp	gpm	Hp	gpm	Hp
	0	10.8	1.2	14.3	1.6	18.5	2.0			21.6	2.4	24.8	2.8	28.0	3.2	32.2	3.5	35.9	4.0	39.9	4.4	43.6	4.8
	29	10.0	1.2	13.5	1.6	16.9	2.0			19.8	2.4	22.7	2.8	25.9	3.2	28.8	3.6	32.2	4.0	35.4	4.4	38.5	4.8
	58	9.8	1.3	12.9	1.7	16.4	2.1			19.3	2.5	21.9	3.0	24.8	3.2	27.5	3.6	30.6	4.2	34.3	4.4	36.4	4.8
	88	9.5	1.3	12.7	1.7	15.8	2.1			18.5	2.7	21.4	3.1	24.0	3.6	26.7	4.0	29.8	4.4	32.7	4.8	35.1	5.5
	147	9.0	1.5	12.1	1.9	15.0	2.4			17.7	3.0	20.3	3.5	23.0	4.0	25.6	4.4	28.5	5.0	30.9	5.5	33.8	6.2
	220	8.7	1.9	11.6	2.3	14.3	3.0			16.9	3.6	19.3	4.2	21.6	4.8	24.3	5.5	27.2	6.0	29.8	6.6	32.5	7.1

Pumps

Identification plate of a Model 464 pump

Identification

1. Model / mm stroke
2. Max. operation revolutions
3. Identification number
4. Capacity
5. Max. pressure

Identification plate

An identification plate on the pump, usually at the front or rear, shows:

- Model / mm stroke
- Max. working revolutions
- Identification number — See below on ID
- Pump capacity — Note the capacity drops a little at higher pressure
- Max. pressure — Some HARDI diaphragm pumps go to 20 or 25 bar

The table indicates the capacity output ranges for the various models.

Model	Capacity range (l/min)	Capacity range (US gpm)
503	14 to 16	3.6 to 4.2
603	26 to 31	6.8 to 8.2
321	48 to 73	12 to 19
1203	99 to 108	26 to 28
1303	114 to 136	30 to 36
364	140 to 194	37 to 51
464	280 to 349	74 to 92

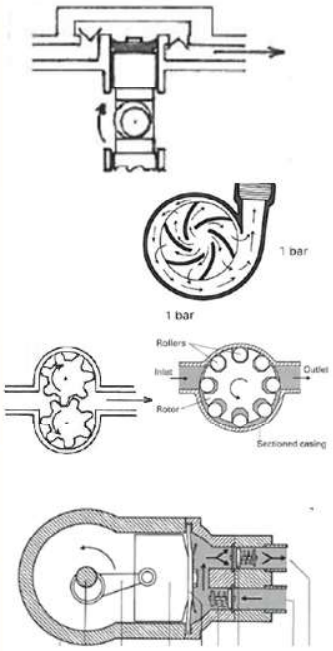
The identification number (ID)
First 2 digits are the production year
Next 6 digits are order number
Last 4 digits are serial number

The power usage is relatively low.
Pump life can be extended by operating at lower pressures and lower revolutions, using the correct grease and cleaning it after the spray job.

Pumps

Types of pumps used in agriculture

Pump type	Advantage	Disadvantage
Piston	High pressure (80 Bar +) Proportional output	High wear rate Must not run dry
Centrifugal	High capacity	Capacity drops (< 10 Bar) Cannot prime Output not proportional
Roller vane Gear	Compact	High wear rate Must not run dry Low capacity
Diaphragm, oil filled	High pressure (40 to 60 Bar) Proportional	Difficult to service Oil pesticide mix
Diaphragm, dry	Long life Proportional Easy to service	Max. pressure 20 bar

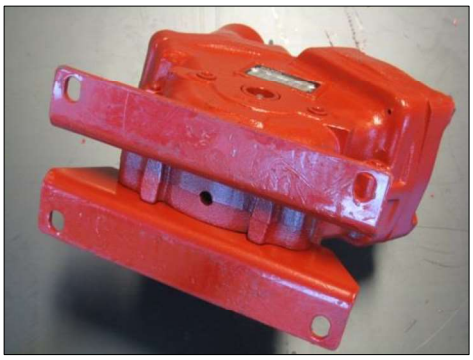


Diaphragm pump advantages

The diaphragm pump is the founding component of the company. The advantages to the user gave benefits no other pumps could offer.

- Self-priming (can suck liquid when filling)
- Able to run dry (no damage)
- Easy to service (customer can do this)
- Grease lubricated (dry sump, drained housing)
- Rotates clockwise or anticlockwise (no damage)
- Chemical resistant valves and diaphragms

The HARDI pumps are robust, easy to service and simple with crankcases and covers made of cast. The crankcase has a drain hole at the bottom. When spray liquid leaks from this drain, the diaphragm needs to be changed. If the pump was oil lubricated, i.e. wet sump, the oil will contaminate the spray liquid and the spray liquid will probably damage the pump bearings.



Pumps

Key identifying features

Model 500 series (500, 503)

- One diaphragm
- Conical or straight shaft
- ¾” inlet and outlet

Model 600 series (600, 603)

- Two diaphragms with V configuration
- Conical or straight shaft
- Detachable feet
- Height: 263 mm
- ¾” inlet and outlet

Model 1200 series (1200, 1202, 1203)

- Two diaphragms with V-configuration
- Conical or straight shaft
- Cast iron feet
- Height: 320 mm
- 1200: ¾” inlet and outlet
- 1202 and 1203: 1¼” inlet and 1” outlet

Model 320 series (320, 321)

- Two diaphragms with Boxer (opposed) configuration
- ¾” inlet and outlet

Model 1300 series (1300, 1301, 1302, 1303)

- Three diaphragms
- 1300: ¾” inlet and outlet. 1301, 1302 and 1303: 1¼” inlet and 1” outlet
- 1302 and 1303: Have ribbed, synthetic connection tubes in valve chambers

Model 360 series (360, 361, 363, 364)

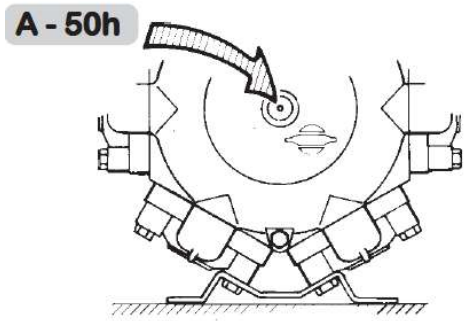
- Six diaphragms
- Length: 222 mm
- 361and some 363: 1¼” inlet and 1”outlet
- 363: 1½” inlet and 1”outlet
- 364: Black covers over top 4 valve covers, 2 grease nipples under pump
- 6 spline is for 540 r/min and 21 spline is for 1000 r/min

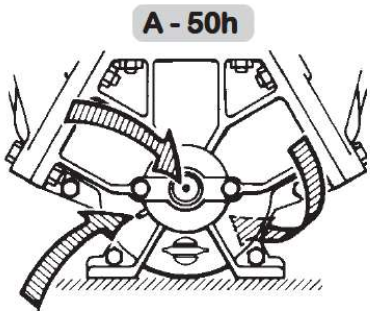
Model 460 series (460, 461, 462, 463, 464)

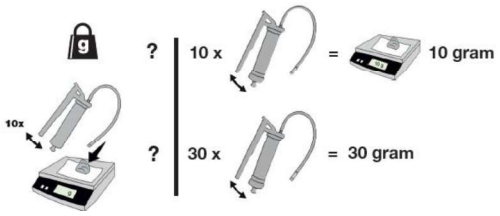
- Six diaphragms, introduced early 1998
- Length: 264 mm
- 460: 1½” inlet and 1¼”outlet; 462: 1½” and 2” inlet and 1¼”outlet
- 463: 2” inlet and 1¼”outlet; Valve covers with boss for connecting rod bolt
- 464: Black covers over top 4 valve covers, 2 grease nipples under pump
- 6 spline is for 540 r/min & 21 spline is for 1000 r/min

Pumps

Lubrication points







Lubrication

The HARDI pumps require greasing every 50 hours of work. Most pumps have just one central grease point found on the crankshaft. There are 3 exceptions:

- Model 1300 pumps: There are 3 grease points; one on the shaft and one on each side of the pump near the centre of the crankcase.
- Model 464 and 364 pumps: There are 2 grease points at the bottom of the pump.

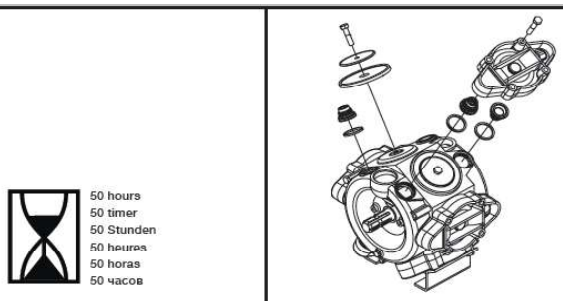
Some of the older pumps with a through-going shaft require removal of the transmission shaft for access to the grease point.

The recommended grease for pump lubrication is HARDI Pump Grease Lithium V550, Ref. No. 28164600. The specification is NLGI 1, 550cSt @ 40^0 C.

Normal service, diaphragm renewal and bearing replacement require different amounts of grease.

Pumps

Lubrication chart



50 hours
50 timer
50 Stunden
50 heures
50 horas
50 часов

Normal operation
Normal drift
Normalbetrieb
Fonctionnement normal
Operación normal
Нормальная операция

Diaphragm renewal
Membran fornyelse
Membranerneuerung
Renouvellement diaphragm
Renovación de diafragma
Обновление Диафрагма

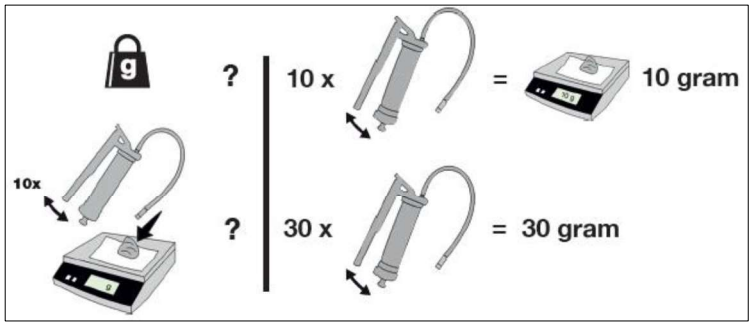
New bearings
Nye lejer
Neue Lager
Nouveaux roulements
Rodamientos nuevos
Новые подшипники

Model	gram total	ounce total	gram total	ounze total	gram total	ounze total
500 - 503	6	0.21	40	1.42	60	2.12
600 - 603	10	0.35	60	2.12	100	3.53
321	10	0.35	60	2.12	100	3.53
1200 - 1203	13	0.46	90	3.17	130	4.59
1300 - 1303	3 x 5	3 x 0.18	3 x 35	3 x 1.23	3 x 50	3 x 1.76
360 - 363	50	1.76	350	12.35	500	17.64
364	2 x 30	2 x 1.06	2 x 200	2 x 7.05	2 x 300	2 x 10.59
460 - 463	50	1.76	350	12.35	500	17.64
464	2 x 30	2 x 1.76	2 x 200	2 x 7.05	2 x 300	2 x 10.59

Lubrication

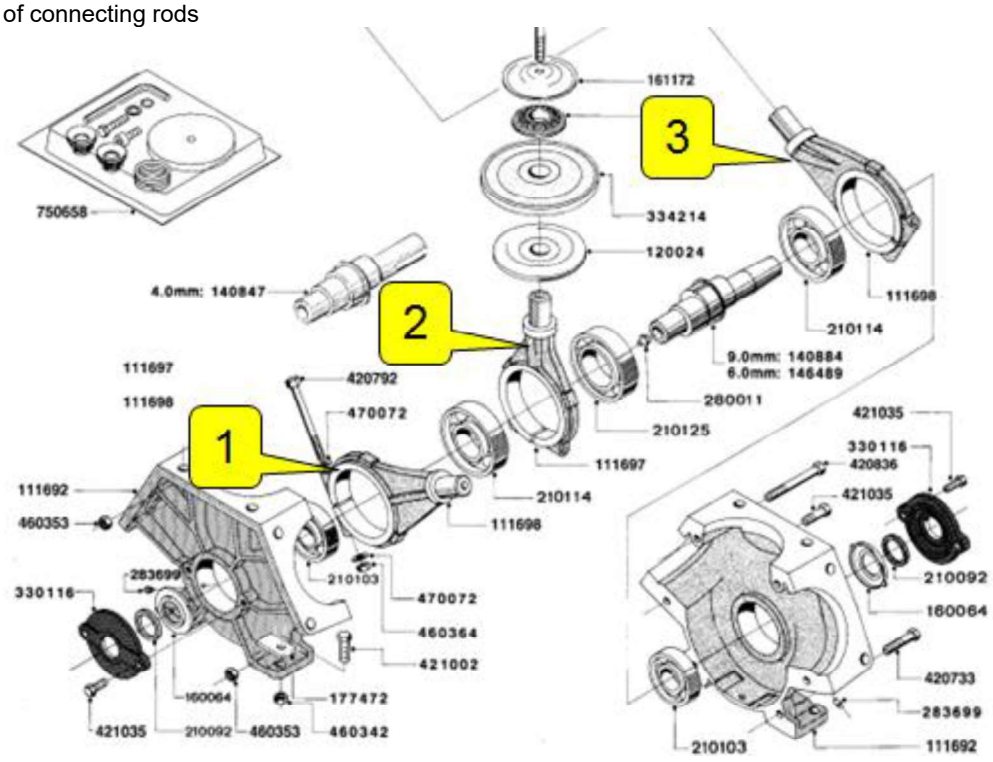
The amount of grease needed depends on the intervention. A table from the instruction book will describe the amount needed.

To determine the amount of grease delivered from a grease gun, pump 10 full strokes onto a scale to measure the weight delivered. Now you can calculate the amount with more or less grease gun pump strokes.



Pumps

Alignment of connecting rods



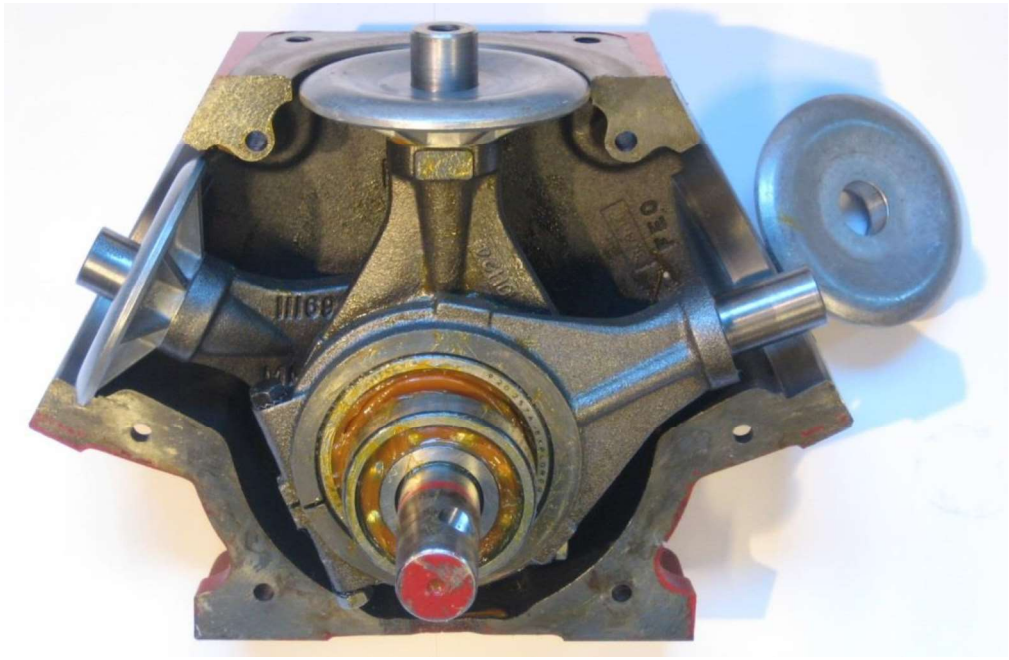
Connecting rod position for models 600, 320, 1200 and 1300

If the pumps are completely disassembled for bearing replacement, it is important to place the connecting rods correctly at re-assembly. Failure to do so will cause excessive pulsations in the liquid delivery.

The parts drawings are quite helpful as they show the correct orientation. Looking from the transmission shaft side, the first connecting rod must be orientated so it points to the right.

Pumps

Alignment of connecting rods



Connecting rod position for models 600, 320, 1200 and 1300

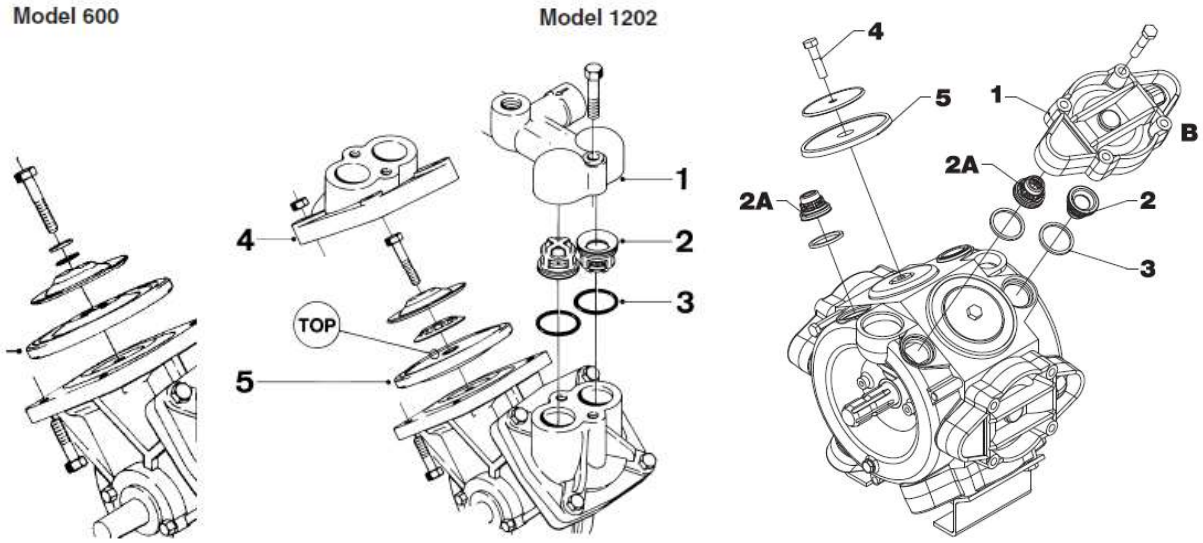
Correct assembly of the connecting rods on a model 1303 pump with pump shaft facing you. If you “shake hands” with the pump, the first connecting rod is always on the right-hand side.

Torque settings

Pump model	Valve cover (Nm)	Diaphragm cover (Nm)	Diaphragm bolt (Nm)
503 and 603	50	50	25
321	60	60	60
1203 and 1303	80	80	80
364 and 464	90	-	90

Pumps

Basic overhaul



Changing valves and diaphragms

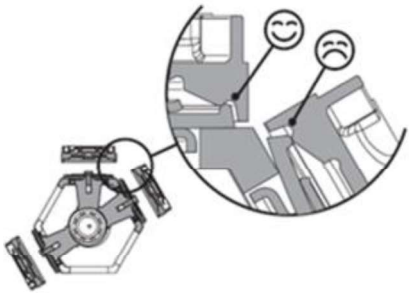
If the pump leaks liquid from the crankcase, the diaphragm needs to be changed. If the liquid system cannot aspirate and produce pressure or it is pulsating, it may be a damaged valve. Before opening the pump, it is wise to have a pump kit on hand. The sprayer instruction book gives you more specific details. General guide:

Valves

Remove the covers (1). Before changing the valves (2), note the orientation. Note that on the older 6 diaphragm pumps, one or two valves with an air bleed hole in the valve flap are used. They are colour-coded white. Note the placement (2A). Use new gaskets (3) at re-assembly.

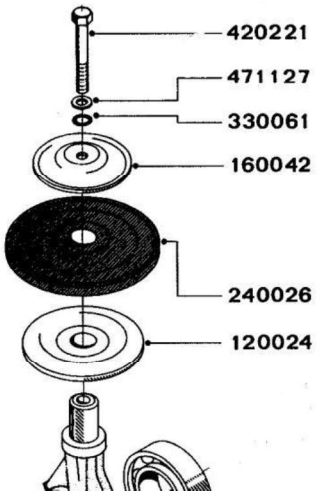
Diaphragms

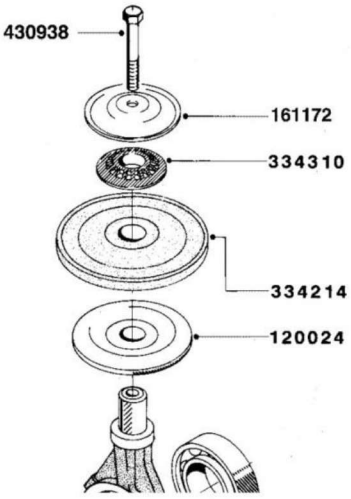
Remove the diaphragm cover (4).
The diaphragm (5) can now be changed. Note the orientation with “TOP” on the upside.
Do not distort it when re-tightening the covers as the diaphragm will not seal properly.
Re-grease the pump if liquids have reached the crankcase.
Do not over-grease and check the drain hole is clear.



Pumps

Older (black) and new version (yellow) diaphragm for model 1200 and 1300 series pumps





Diaphragms and older pump models

The diaphragm material and shape has changed over the years. The older diaphragms were thicker, coloured black and made of nitrile. The present diaphragms are thinner, yellow in colour and are made of polyurethane. They have “TOP” on the side that is to face up. The new material has better resistance to chemicals and the thinner diaphragm has a longer mechanical life.

The new design diaphragm can be fitted to the older pumps. Spacers are supplied in the overhaul kits. Top plate and bolt are now made of stainless steel for a longer life and these are also supplied in the overhaul kit.

Pumps

Over-greasing 	No filtration on filling equipment 
Cavitation damage 	Wrong parts installed 

Typical faults and remedies

Over-greasing

This will hinder or block crankcase drainage. Only the bearings and connecting rods require lubrication.

No filtration

Pump valves jammed with foreign objects indicate that filled water has not been filtered. If using a filling device, place a filter on the filling line before the liquid reaches the sprayer. The picture shows an in-line suction filter (Ref. No. 72050000) for 2½" hose with a course 30 mesh filter insert.

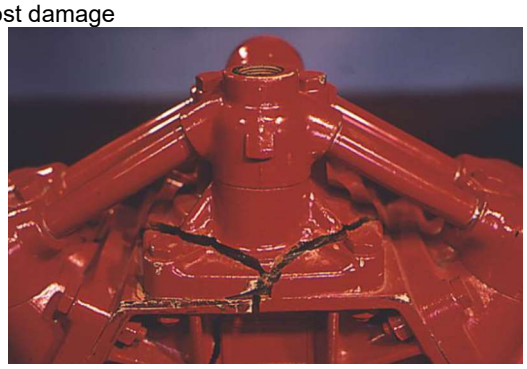
Cavitation

This is caused by a high vacuum on the suction side of the pump. The high vacuum is in turn caused by under-dimensioned suction lines and fittings, a flow restricting suction filter or a blocked suction filter.

Wrong parts; damaged diaphragm covers

This is due to an incorrect combination of connecting rod and crankshaft. These parts are matched i.e. 10 mm con-rod is for a crankshaft with a 10 mm stroke.

Pumps

Frost damage 	Chemical damage 
Mechanical damage 	

Typical faults and remedies

Frost damage

The best preventative to frost damage is running the sprayer with anti-freeze (glycol) before winter storage. Some pumps are equipped with drain plugs but draining the pump will not guarantee frost damage to other parts of the sprayer.

Chemical damage

Pesticides using petro-chemical solvents are very harsh on synthetic components. They typically have an odour similar to kerosene. The diaphragms will swell and begin to flake. If the sprayer has not been cleaned before storage, this will leave the components in contact with the solvent for a long time and chemical damage may be expected.

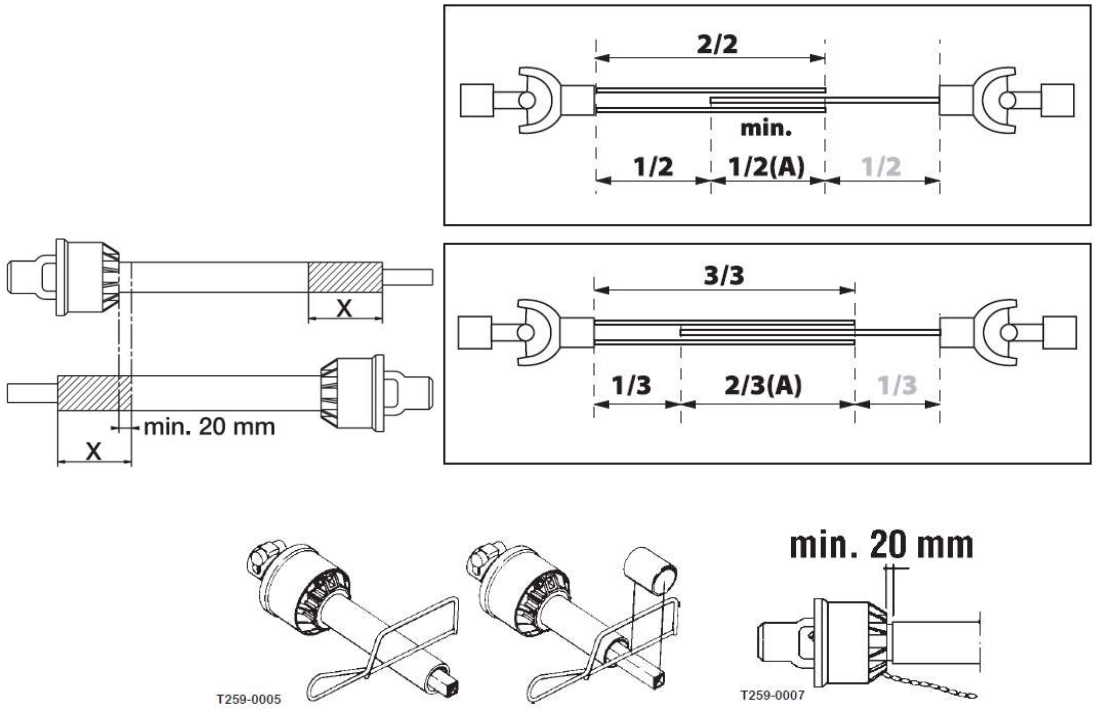
Mechanical damage

Normal mechanical lifetime for diaphragms is approximately from 1000 to 2000 hours. If the spraying is always done at high pressures and/or high revolutions, this will shorten the diaphragm life. Damage will look like a knife cut.

Once the diaphragm is perforated, the pump will leak liquid from the crankcase.

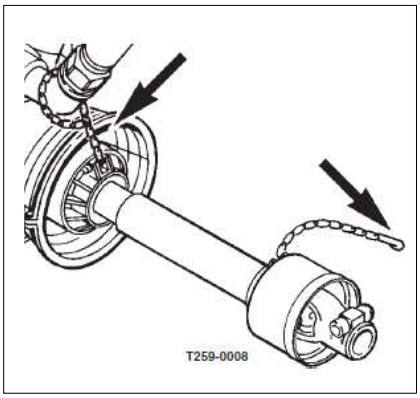
Pumps

Transmission shafts

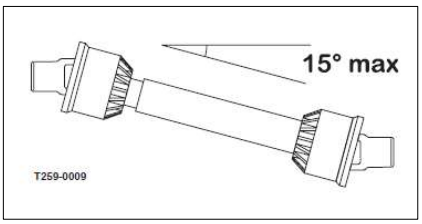


Transmission shaft

The transmission or Cardan shaft supplies power from the tractor to the sprayer. Universal joints allow for changes in alignment. For applications where the angle between tractor and sprayer are acute, a wide-angle shaft should be used otherwise the universal joint bearings will be damaged



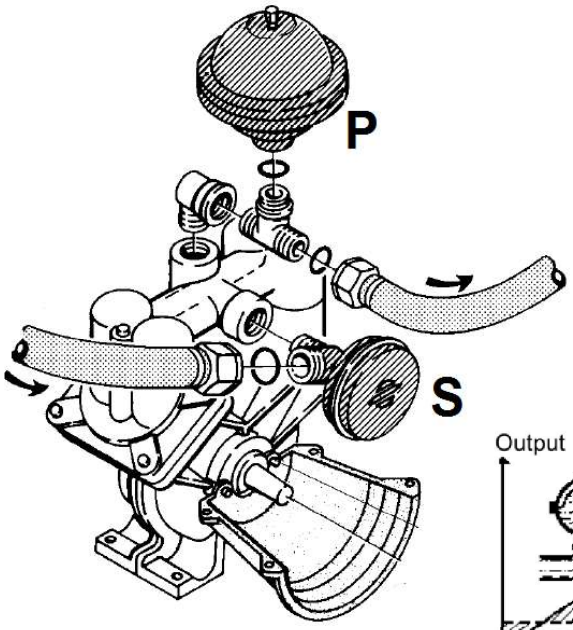
The shaft may need to be shortened at the first installation. If it is too long, it or the pump will be damaged. Before installation, set the sprayer and tractor so the shortest distance possible is found between sprayer pump and tractor P.T.O. Now compare with the transmission shaft and shorten if needed. The recommended overlap (A) should be 2/3 of the shaft length. The shaft must have a minimum overlap (A) of ½ the length.

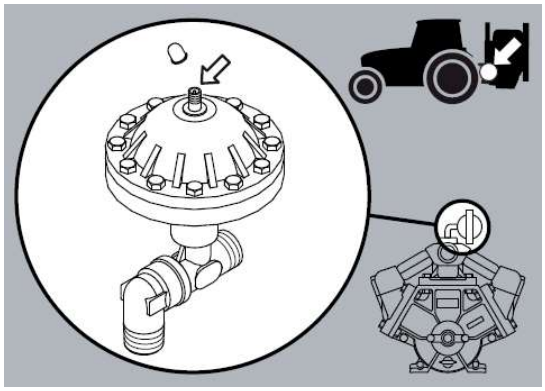


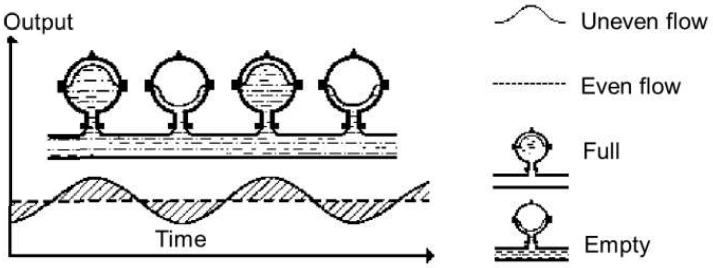
For operator safety, the transmission shaft guards must be intact and must not rotate. Avoid angles greater than 15^0 as this will shorten bearing life. Refer to transmission shaft instructions supplied with the shaft.

Pumps

Suction (S) and Pressure (P) dampers







Suction and pressure damper

Many of the smaller pumps can be supplied with a suction (S) and pressure (P) damper. The dampers remove the pulsations caused by the small number of diaphragms. The 6-diaphragm pumps do not require a suction or pressure damper

The suction damper is a passive diaphragm and does not require control. The pressure damper is pre-charged from the factory with 2 bar (30 psi) pressure.

To check for a damaged pressure damper diaphragm, first unscrew the damper from the “T” piece and then shake it. If you hear a sloshing sound, it is damaged.

Spray pressure bar	Damper pressure bar	Spray pressure psi	Damper pressure psi
1.5 - 3	0 - 1	20 - 45	0 - 15
3 - 15	1 - 3	45 - 220	15 - 45
15 - 25	3 - 4	220 - 360	45 - 60