# Towards a Definitive Pump-testing System

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**Abstract**

*Pump performance testing has been formalised by the development of semi-portable test equipment using a new application for a venturi flow meter. Flow rate, lift capacity and maximum pressure can be determined accurately, enabling the condition of pumps to be assessed easily. A system for documenting pump performance and equipment servicing has also been developed.*

## Introduction

Until recently, the Forestry Commission, Tasmania, undertook an annual pump maintenance programme in which all necessary repair work was carried out at the Moonah workshop. Spare-parts inventory was minimised and a high level of expertise was concentrated in a small number of fitters. Staff from the three field workshops attended Moonah annually to maintain skills sufficient for field repairs to equipment.

In the past, pumps with a flow capacity of up to 600 litres/min were tested by running the pumps for 20 minutes from a 200-litre test tank in a flood prime recirculating mode. Pumps with a capacity larger than 600 litres/min were tested in a local reservoir in the same manner. The only performance parameter measured was pressure at shut-off. Pumps which did not attain an acceptable pressure were repaired or removed from service. Formal record keeping was minimal, with units which performed satisfactorily being labelled with the service date and a 'Tested and OK' tag.

Within the limitations of the test procedures, the maintenance programme was of high quality. However, it provided no information on pump flow rates or lift capacity. These parameters are critical determinants of the efficiency of the pump and of its ability to work effectively in adverse conditions.

Following a departmental re-organisation, the pump maintenance programme was de-centralised to the Forestry Commission field workshops. Additional staff were involved and it became obvious that a consistent approach was needed, including a standard testing procedure and a means of recording the results to allow year-to-year monitoring of pump performance.

The requirements of a formal pump-testing system were established as being:

- Simplicity, low cost, accuracy and consistency;
- Capable of simulating suction lift;
- Capable of measuring flow at varying pressures;
- Capable of measuring rotational speed (rpm);
- A user-friendly service schedule and recording system.

The present paper outlines a simple but highly accurate method of testing pumps using a new application for a venturi flow meter. The equipment is robust, inexpensive and does not require regular recalibration and checking. It is also semi-portable and can be transported easily.

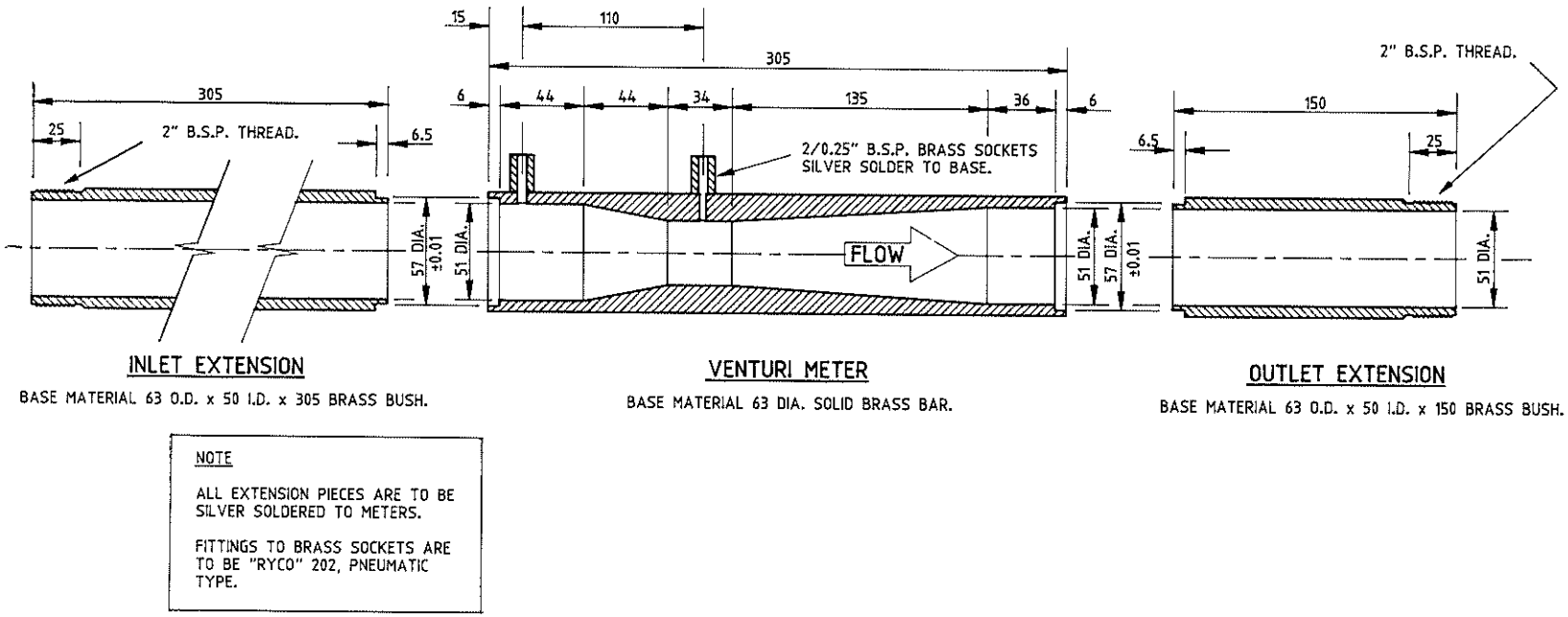


*Figure 1. Dimensions of a venturi meter capable of handling flows of 0–600 litres/min. (Scale = 1:2.5)*

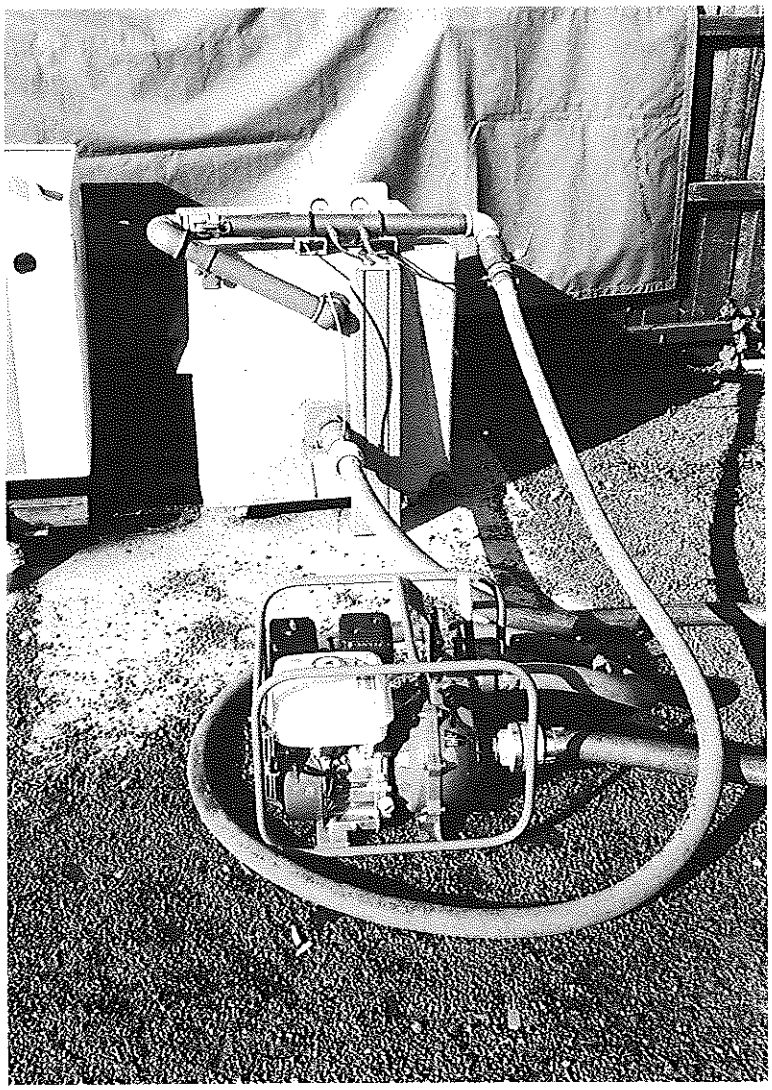

*Photo 1. The pump-testing equipment. A pump (foreground) is connected to a water tank (behind) onto which the venturi tube is mounted. The manometer is shown in front of the tank attached to the venturi.*

**Venturi flow meters**

Venturi flow meters make use of the relationship between fluid flow and pressure such that the constriction in a venturi tube causes an increase in fluid velocity and a corresponding decrease in pressure. The pressure change can be measured using a manometer attached to the venturi.

In any venturi, the size of the pressure decrease can be related directly to flow rate using Formula 1 (Appendix 1) which is derived from Bernoulli's equation and the equation of continuity (for example, see Kinsky 1982). A chart can be prepared using this formula which permits the mercury height difference (in mm) in the manometer to be converted directly to flow rate. The chart shown in Appendix 2 has been prepared for a venturi tube of the dimensions shown in Figure 1 (0–600 litres/min capacity). If the dimensions of the tube are varied, a new table is required and can be produced easily using the formula.

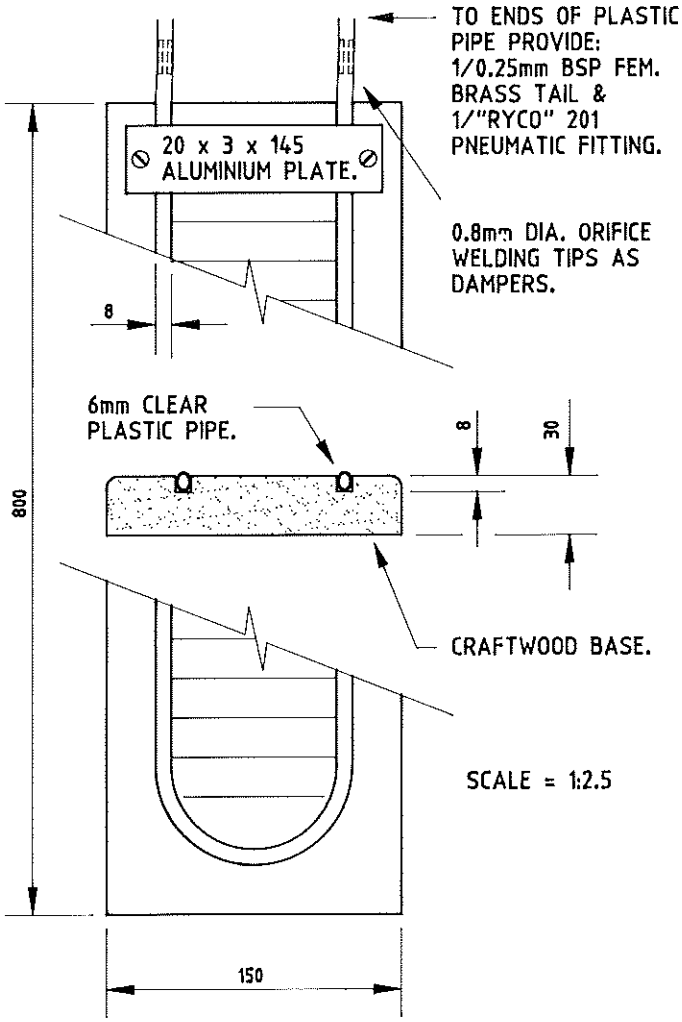


*Figure 2. Dimensions of the pump-testing manometer.*

Because the relationship between pressure and flow in a venturi is exponential, it was found impossible to construct a single venturi tube capable of handling the full flow range encountered in pumps used by the Forestry Commission (0–1200 litres/min). Three venturi tubes were constructed to handle flows of 0–150 litres/min, 0–600 litres/min (Figure 1) and 500–1200 litres/min. The same manometer serves all venturi tubes (Figure 2).

Consistent results among venturi tubes of the same nominal size depend on accurate reproduction of dimensions, angles and surface finish quality. Providing each venturi tube is calibrated with its own flow chart, it will provide accurate and reproducible readings.

## Pump testing

Water is circulated through a heavily baffled cube-shaped test tank on which the venturi flow meter and manometer are mounted (Photos 1, 2, 3). A 300-litre tank can accommodate flow rates to 600 litres/min. Flow rates to 1200 litres/min can be accommodated in a 700-litre tank, with suction and discharge outlets in different baffle compartments.

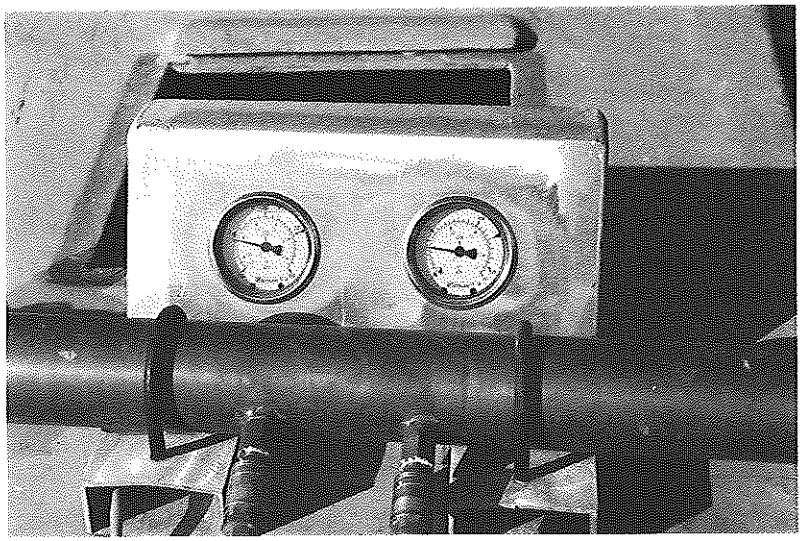

*Photo 2. The venturi flow meter mounted on the tank.*

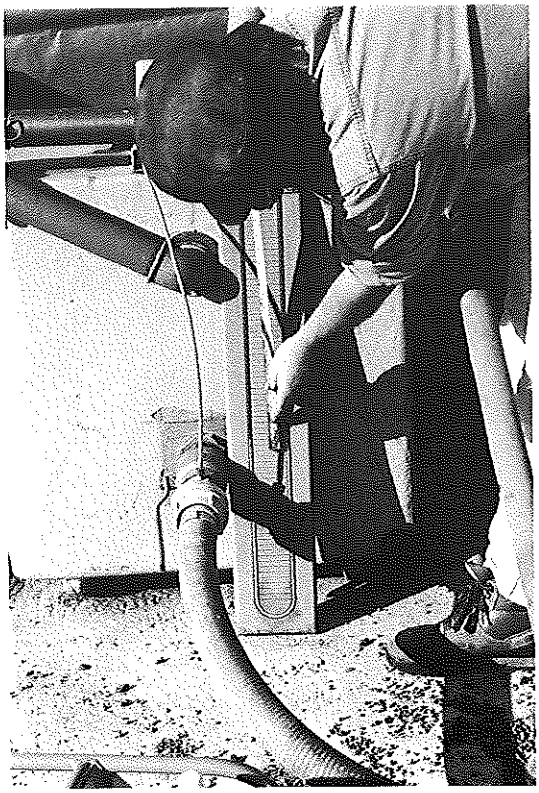

*Photo 3. Measuring the mercury height differential in the manometer.*

All tests are conducted with the pump engine set at full operating rpm as measured with an impulse tachometer. Readings for maximum flow are obtained with both suction and pressure line valves open. The negative pressure is then read from the vacuum gauge attached to the suction line, and recorded (Figure 3, item 3). The mercury height differential on the manometer is measured directly using a ruler and the flow rate is read from the flow chart and inserted at item 3 in Figure 3.

The flow rate at a lift equivalent to 3 m is obtained by closing the suction valve until the vacuum gauge reads -30 kPa. The flow rate is calculated from the manometer reading and the flow table, and recorded in Figure 3, item 4. A similar procedure is followed for a lift equivalent to 5 m or -50 kPa (Figure 3, item 5). Simulating lifts of more than 5 m should be avoided due to the likelihood of inducing cavitation in the pump chamber.

Flow rates at a range of pressure heads are determined by progressively closing the pressure line valve, while watching the gauge on the pressure line. When the desired pressure is reached, a reading is taken from

# FORESTRY COMMISSION : PUMP PERFORMANCE SHEET

PERFORM TEST AS INDICATED - ANSWER ALL QUESTIONS

DATE ..... ASSET NO ..... PUMP TYPE .....

District ..... General Condition Good ☐ Ok ☐ Poor ☐

All tests to be performed with Engine at full operating revs.

1. Max .engine revs. on full throttle at shut off pressure ☐ RPM

   Max . Engine revs. on full throttle at full flow ☐ RPM

2. Max Pressure at shutoff ☐ kPa

| | | | | | Equivalent Head in metres |
|---|---|---|---|---|---|
| 3. | Suction Pressure at max flow : ☐ | FLOW | ☐ | L/Min | |
| 4. | At a suction pressure of : | -30 kpa | FLOW ☐ | L/Min | -3M |
| 5. | At a suction pressure of : | -50 kpa | FLOW ☐ | L/Min | -5M |
| 6. | At a pressure head of : | 200 kpa | FLOW ☐ | L/Min | 20M |
| 7. | At a pressure head of : | 400 kpa | FLOW ☐ | L/Min | 40M |
| 8. | At a pressure head of: | 600 kpa | FLOW ☐ | L/Min | 60M |
| 9. | At a pressure head of : | 800 kPa | FLOW ☐ | L/Min | 80M |
| 10. | At a pressure head of : | 1000 kpa | FLOW ☐ | L/Min | 100M |
| 11. | At a pressure head of : | 1200 kpa | FLOW ☐ | L/Min | 120M |
| 12. | At a pressure head of : | 1400 kpa | FLOW ☐ | L/Min | 140M |
| 13. | At a pressure head of : | 1600 kpa | FLOW ☐ | L/Min | 160M |
| 14. | At a pressure head of : | 1800 kpa | FLOW ☐ | L/Min | 180M |

Comments:

Tested By .....

*Figure 3. Pump performance sheet.*

the manometer. The flow rate is determined via the flow table and inserted in Figure 3 (items 6–14). Suction is left unrestricted during this test.

## Documentation

Documentation for both pump performance (Figure 3) and equipment servicing (Appendix 3) has been developed, enabling the history or condition of any pump to be easily checked. The information is stored in a computer database and can be retrieved whenever required.

## Discussion

With the development of the test equipment, quantitative pump testing is now a routine process. The ability to accurately measure flow rates and pressures provides a real indication of pump condition and the problem that 'it works beautifully but it won't pump water' no longer occurs.

Additional benefits have come to light with the manufacture and commissioning of the test equipment. Isolation and diagnosis of pumping faults in tanker equipment have become easier, especially in cases where these faults have been difficult to find by more conventional means. Furthermore, by pin-pointing faults or problem areas, the test equipment has indicated that there is potential for much improved efficiency in tanker plumbing systems. Following from this, the hydraulic 'cleaning up' of pipe-work design, particularly on the suction side, has resulted in better operating performance, lower running costs and a reduction in time lost for repair work.


## Acknowledgements

We thank Tim Geard and Ron Neve (Forestry Commission, Tasmania) and Tony Blanks (Department of Environment and Land Management, Tasmania) for comments on the draft manuscript. Tim Geard also provided the photos used in the paper.


## References


Kinsky, R. (1982). *Applied Fluid Mechanics.* McGraw-Hill Book Co., Sydney. (Reprinted 1989)


*Appendix 1. Formula used to contruct the flow chart.*

$$\dot{V} = C_d A_2 \sqrt{\frac{2gh_p}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

where $\dot{V}$ = flow of water in $m^3/sec$
$C_d$ = the coefficient of discharge
$g$ = acceleration due to gravity (an average value is 9.8 $m/sec^2$)
$A_1$ = the inside area of the venturi tube before the constriction ($m^2$)
$A_2$ = the inside area at the narrowest point of the venturi tube ($m^2$)
$h_p$ = the differential pressure head

and $$h_p = \left(\frac{\rho_i}{\rho} - 1\right) h$$

where $\rho_i$ = density of mercury ($kg/m^3$)
$\rho$ = density of the fluid ($kg/m^3$) flowing through the tube (varies for different fluids)
$h$ = height difference of mercury (mm) between the left and right side of the manometer

*Appendix 2. Flow chart used with the Forestry Commission's venturi flow meter (range 0-600 litres/min). Shaded numbers refer to the mercury height differential (mm): the value is read as tens across the table and units down the table. Unshaded numbers refer to flow rates (litres/min) and these are obtained by intersecting the row and column representing the value of the mercury height differential.*

| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | 94 | 133 | 162 | 187 | 210 | 230 | 248 | 265 |
| 1 | 30 | 98 | 136 | 165 | 190 | 212 | 231 | 250 | 267 |
| 2 | 42 | 103 | 139 | 168 | 192 | 214 | 233 | 251 | 268 |
| 3 | 51 | 107 | 142 | 170 | 194 | 216 | 235 | 253 | 270 |
| 4 | 59 | 111 | 145 | 173 | 197 | 218 | 237 | 255 | 272 |
| 5 | 66 | 115 | 148 | 175 | 199 | 220 | 239 | 257 | 273 |
| 6 | 73 | 119 | 151 | 178 | 201 | 222 | 241 | 258 | 275 |
| 7 | 78 | 122 | 154 | 180 | 203 | 224 | 243 | 260 | 276 |
| 8 | 84 | 126 | 157 | 183 | 205 | 226 | 244 | 262 | 278 |
| 9 | 89 | 129 | 160 | 185 | 207 | 228 | 246 | 263 | 280 |

| | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 281 | 296 | 311 | 325 | 338 | 351 | 363 | 375 | 386 |
| 1 | 283 | 298 | 312 | 326 | 339 | 352 | 364 | 376 | 387 |
| 2 | 284 | 299 | 314 | 327 | 340 | 353 | 365 | 377 | 389 |
| 3 | 286 | 301 | 315 | 329 | 342 | 354 | 367 | 378 | 390 |
| 4 | 287 | 302 | 316 | 330 | 343 | 356 | 368 | 379 | 391 |
| 5 | 289 | 304 | 318 | 331 | 344 | 357 | 369 | 381 | 392 |
| 6 | 290 | 305 | 319 | 333 | 346 | 358 | 370 | 382 | 393 |
| 7 | 292 | 307 | 321 | 334 | 347 | 359 | 371 | 383 | 394 |
| 8 | 293 | 308 | 322 | 335 | 348 | 360 | 372 | 384 | 395 |
| 9 | 295 | 309 | 323 | 337 | 349 | 362 | 374 | 385 | 396 |

| | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 | 260 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 398 | 408 | 419 | 429 | 439 | 449 | 459 | 469 | 478 |
| 1 | 399 | 410 | 420 | 430 | 440 | 450 | 460 | 469 | 479 |
| 2 | 400 | 411 | 421 | 431 | 441 | 451 | 461 | 470 | 480 |
| 3 | 401 | 412 | 422 | 432 | 442 | 452 | 462 | 471 | 481 |
| 4 | 402 | 413 | 423 | 433 | 443 | 453 | 463 | 472 | 481 |
| 5 | 403 | 414 | 424 | 434 | 444 | 454 | 464 | 473 | 482 |
| 6 | 404 | 415 | 425 | 435 | 445 | 455 | 465 | 474 | 483 |
| 7 | 405 | 416 | 426 | 436 | 446 | 456 | 466 | 475 | 484 |
| 8 | 406 | 417 | 427 | 437 | 447 | 457 | 467 | 476 | 485 |
| 9 | 407 | 418 | 428 | 438 | 448 | 458 | 468 | 477 | 486 |

| | 270 | 280 | 290 | 300 | 310 | 320 | 330 | 340 | 350 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 487 | 496 | 505 | 513 | 522 | 530 | 538 | 546 | 554 |
| 1 | 488 | 497 | 505 | 514 | 523 | 531 | 539 | 547 | 555 |
| 2 | 489 | 498 | 506 | 515 | 523 | 532 | 540 | 548 | 556 |
| 3 | 490 | 498 | 507 | 516 | 524 | 533 | 541 | 549 | 557 |
| 4 | 490 | 499 | 508 | 517 | 525 | 533 | 542 | 550 | 558 |
| 5 | 491 | 500 | 509 | 517 | 526 | 534 | 542 | 550 | 558 |
| 6 | 492 | 501 | 510 | 518 | 527 | 535 | 543 | 551 | 559 |
| 7 | 493 | 502 | 511 | 519 | 528 | 536 | 544 | 552 | 560 |
| 8 | 494 | 503 | 512 | 520 | 528 | 537 | 545 | 553 | 561 |
| 9 | 495 | 504 | 512 | 521 | 529 | 537 | 546 | 554 | 561 |

| | 360 | 370 | 380 | 390 | 400 | 410 | 420 | 430 | 440 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 562 | 570 | 578 | 585 | 593 | 601 | 609 | 616 | 623 |
| 1 | 563 | 571 | 578 | 586 | 593 | 602 | 609 | 617 | 624 |
| 2 | 564 | 572 | 579 | 587 | 594 | 603 | 610 | 617 | 624 |
| 3 | 565 | 572 | 580 | 587 | 595 | 604 | 611 | 618 | 625 |
| 4 | 565 | 573 | 581 | 588 | 596 | 604 | 612 | 619 | 626 |
| 5 | 566 | 574 | 581 | 589 | 596 | 605 | 612 | 619 | 626 |
| 6 | 567 | 575 | 582 | 590 | 597 | 606 | 613 | 620 | 627 |
| 7 | 568 | 575 | 583 | 590 | 598 | 607 | 614 | 621 | 628 |
| 8 | 568 | 576 | 584 | 591 | 599 | 607 | 614 | 622 | 629 |
| 9 | 569 | 577 | 584 | 592 | 599 | 608 | 615 | 622 | 629 |

# FORESTRY COMMISSION : PUMP SERVICE SHEET

PERFORM SERVICE AS INDICATED - TICK WHEN COMPLETED

DATE ..... ASSET NO ..... S/NO.....

Record unit in job book. ☐

Identify any other problems prior to service. ☐
(If any notify FMB or outside agency prior to commencenment) (Y/N)

Assess whether unit is economical to repair. ☐ (Y/N)

Service engine :
- drain crankcase (and refill if 4 stroke). ☐
- change or clean oil filter. ☐
- change or clean air filter. ☐

Fuel system :
- drain completely. ☐
- clean out thoroughly. ☐
- replace fuel filter. I/A ☐
- reset static settings. ☐

Starting system :
- recoil :
  - check rope. ☐
  - lubricate. ☐
  - check operation. ☐
- electric :
  - battery condition. I/A ☐
  - switch & solenoid operation. ☐
  - starter operation. ☐

Pump :
- change gear oil. I/A ☐
- check gland or stuffing box. ☐
  (If performance is down dismantle)
- check impellor for obstructions. ☐
- check ring clearance. ☐
- check impellor-housing clearance. ☐

Ignition System :
- change spark plug. ☐
- check spark. ☐
- leads. (high & low tension). ☐
- stop switch. ☐

Testing unit :
- engine.
  - ease of starting. ☐
  - idle speed. ☐
  - full revs (loaded). ☐
  - governor operation. ☐
  - oil & fuel leaks. ☐
  - general engine condition. ☐
- pump :
  - primer operation. ☐
  - foam system operation. ☐
  - seal condition. ("Darley" 20-60 drips/min) ☐
  - max operating pressure. (kpa) ☐
  - suction head tested to. (kpa) ☐

Performance test (if available) :
.....
.....

Time taken in hours :
- to remove and refit pump from tanker. ☐
- to service pump/schedule. ☐
- to complete extra work. ☐
- to test and record performance data. ☐

Complete :
- drain fuel and water, leave engine on compression stroke. ☐
- attach a copy of service sheet with delivery instructions. ☐
- dispatch to destination. ☐

Comments

Additional work required

Mechanic.....