OPERATING AND MAINTENANCE MANUAL

DANDO DUKE STAGE IV
CABLE PERCUSSION RIG
TRAILER MOUNTED

SOCOTEC UK LTD.

DANDO DRILLING INTERNATIONAL LTD. REF.: SO/1950010
(PLEASE QUITE THIS NUMBER WHEN ORDERING SPARE PARTS)

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SECTION 1

GENERAL

SECTION 1 - GENERAL

1.1 GENERAL SAFETY

As Designers, Manufacturers and Suppliers of Specialised Equipment, Dando Drilling International Ltd ensure so far as it is reasonable that our products are safe and without risk to health when properly used.

You are requested to take the necessary steps to ensure that the appropriate information is made available to all those involved with the proper use of our products, or to anyone who may work on, purchase, or otherwise acquire such products for their own use.

1.2 OPERATING AND MAINTENANCE MANUAL

Dando Drilling International Ltd support all new products being supplied to their customers with a comprehensive Operator Manual which clearly defines mandatory instructions for the operation, safe use and maintenance of the products. Further, where proprietary items are incorporated into products of Dando Drilling International Ltd, comprehensive Operators Manuals on these items are also supplied, together with the Operating Manuals etc. on any vehicle or other carrier supplied as part of a contract.

It is the responsibility of the owners or hirers of such products to ensure that operators are provided with these Manuals and are suitably instructed regarding the purpose of these Manuals and safety instructions. In addition, operators should be suitably and adequately trained in the use of the product.

1.3 CODE OF SAFE DRILLING PRACTICE

It is the responsibility of the owners and hirers of this equipment to ensure that the operators of the equipment are aware that drilling sites can be potential hazardous environments, and that safe drilling practice should always be adhered to.

Dando Drilling International draw your attention to the Code of Safe Drilling Practice as published by the British Drilling Association [Ref 1], and would recommend that all operators are fully conversant with all aspects covered by this publication and take the necessary steps to become B.D.A. Accredited Drillers. For operators outside the United Kingdom, we would recommend that their national equivalent to the B.D.A. publication is adhered to.

The Guidance Notes on safety that follow are extracted from the British Drilling Association's publication "Code of Safe Drilling Practice", and Dando Drilling International would like to acknowledge with thanks their permission to reproduce this section. Further guidance on percussion drilling can be found in Guidance for the Operation of Cable Percussion Rigs and Equipment also published by the British Drilling Association [Ref 2].

1.4 SAFETY PRECAUTIONS

WARNING. BREATHING DUST IS DANGEROUS TO HEALTH

1) Operate in a well-ventilated place and use appropriate extraction equipment or a damp cloth to remove dust.
2) Dampen all dust.
3) Dispose of waste in heavy gauge plastic sacks in accordance with legislative requirements.

GENERAL INSTRUCTIONS AND WARNINGS

1.4.1 STARTING RIG ENGINE

Check that all controls are in a neutral/disengaged/minimum position.

1.4.2 LEVELLING THE RIG

Before attempting to raise the mast, ensure that the rig is set up on a firm level base, and all jacks are in contact with the ground.

1.4.3 MAST RAISING

CAUTION: Before attempting to raise the mast, ensure that the mast framework is clear of any obstructions.

1.4.4 DRILLING OPERATIONS

Before commencing any drilling operations, ensure that the spreader bar and stay bars are fitted and secured.

1.4.5 WARNINGS

THIS RIG IS FITTED WITH AN ALTERNATOR

DO NOT disconnect batteries when engine is running.

DO NOT turn ignition key to '0' position on switch while the engine is running.

IF ANY ARC WELDING takes place on the rig **DISCONNECT BOTH BATTERY AND ALTERNATOR**. When brazing, soldering or welding, it is essential that any excessive heat source is kept away from the vicinity of the alternator and any nylon piping or rubber hose.

FAILURE TO COMPLY WITH THESE WARNING WILL LEAD TO COMPONENT DAMAGE AND MAY CAUSE INJURY.

1.4.6 BATTERIES

Ensure that the correct battery polarity is maintained at all times, reversed battery or charger connections may damage the alternator rectifiers. Never disconnect the battery whilst the engine is running.

DO NOT use a naked light when examining the electrolyte level.

When charging the batteries from an external source ensure that the vent covers are removed.

Always disconnect the earth lead from the battery negative (-) terminal when working on the rig engine.

Avoid spilling battery acid on the paintwork. Wash off with water immediately if this occurs.

1.4.7 TRAILER MOUNTED RIGS

WARNING: The trailer on which the rig is mounted is designed with a load carrying capacity for the rig only, unless otherwise specifically stated. Do not add platforms etc. for carrying additional items as this will overload the trailer, contravening the Road Traffic Construction and Use regulations in the United Kingdom.

1.5 GUIDANCE NOTES ON SAFETY

1.5.1 PERSONNEL

a. Drilling may entail the employment of men inexperienced in this class of work. Care should therefore be taken to explain and enforce safety precautions, and to teach good practice in the handling and use of equipment and plant.

b. No workman should be employed on any work unless he has been adequately instructed and trained in that work and is competent to do that work without supervision, or he is working under the instruction and supervision of some person competent to give instruction in and supervision in the doing of that work. This is especially important when employing young persons on drilling sites.

c. Alcohol should not be consumed on the site and persons who have been drinking
should not be allowed on the site.

d. Pranks and horseplay are a common cause of accidents and should be forcefully
discouraged. Safe successful work requires serious attention and good teamwork.

e. Operators should not lift, carry or move any load which is so heavy as to be likely to cause injury. When lifting, it is recommended that the person should stand squarely with a solid footing and should lift the load slowly by straightening the legs rather than the back.

f. Care should be exercised when handling weights which must be moved with artificial means, such as pipe used for casing etc.

g. If pipe is to be moved by rolling by hand, this must be done from the ends and the person must ensure that the hands are kept out of the ends of the pipe. Whenever possible the pipe should be rolled away from the person rolling it.

h. In general, care should be exercised whenever lifting something, be it heavy or light. In the case of lifting and moving heavy weights, chains, ropes and pipe hooks should be checked to ensure that they are in good condition and employees should never stand under a raised load.

i. Visitors to the drilling site are in more danger that the operators, and should be steered clear of operational areas unless the nature of their visit demands otherwise. If necessary, operations should be suspended until visitors have been moved to a safer part of the site.

1.5.2 TRAVELLING TO, ON AND FROM DRILLING SITES

a. Vehicles travelling on public highways must comply with the Highway Code, relevant Road Traffic Acts and with the appropriate Motor Vehicle Regulations currently in force in the United Kingdom or other E.C. country.

b. Before travelling, checks should be made to all vehicles for road worthiness, giving special attention to lights, indicators, screen wipers, registration plates, brakes, brake lights, steering, security of loads, particularly overhanging loads, tyre pressure and wear and lack of mud before proceeding onto a public highway.

c. Important: It is drawn to your attention that the Dando Duke models of drilling rigs are **NOT** trailers and should not be loaded with drilling equipment during travel from drilling site to drilling site.

d. It is important that checks are made of the coupling and/or hitching of the drilling rig to any towing vehicle.

e. Where required, long vehicle signs, caution or towing boards should be securely attached.

f. When towing equipment, correct towing speeds, reversing and manoeuvring procedures should be observed and assistance obtained where necessary. Due regard should be paid to road conditions and visibility at all times. Care should be taken when towing in icy conditions as “jack-knifing” can occur. The safe towing speed should not be exceeded as there is a risk that “snaking” may suddenly develop, which may cause the trailer to lose a wheel.

g. Consideration should be given to other road users who may become impatient and take risks - it is advisable to pull into the side occasionally to let them pass.

h Where wide, long or heavy loads are to be moved it is advisable to have all lights on for road travel, even in broad daylight.

i. On arrival at the site, ground conditions should be checked before driving in, and a watch kept for temporary overhead obstructions.

j. If necessary, an assistant should be used to control traffic if safety dictates.

k. Passengers should not be carried on or around the machine.

l. The driver of the vehicle should check for all round visibility before commencing any manoeuvre, especially reversing. If necessary, an assistant should be used to signal. The presence of an assistant does not relieve the driver of his responsibility, so he should constantly check the rear view in his mirror, and by direct sight.

m. When manoeuvring vehicles, due regard should be paid to soft ground, potholes, gradients, slippery grass and mud, and overhead cables. Special care should be taken when crossing dykes with improvised bridges. At all times, personnel should keep well clear of moving vehicles in case they overturn. Where winches must be used, a watch should be kept for flying ground anchors and rope failures.

n. Loading and un-loading the plant should only be carried out on firm level ground.

o. The vehicle's driver should act as assistant during loading and un-loading operations. Signals should be agreed beforehand and standard procedures followed.

p. When loading or un-loading on a public highway, assistants should be used to hold back traffic. These men should be responsible to the vehicle driver only.

q. Where the access to and from the site does not have good visibility in all directions, traffic leaving the site should be controlled by a person nominated for that purpose.

r. Vehicles should not reverse out of the drilling site onto a public highway.

1.5.3 DRILLING SITE PREPARATORY AND RESTORATION WORKS

a. It is of greatest importance that a proper site appraisal should be made before any work is commenced. The results, together with any records of any underground installations, services, workings, etc., should have been made available to the drilling contractor who in any event should take all reasonable steps to obtain them.

b. A plan of the site showing the location of hazards to site preparatory work and to drilling operations should be prepared before any equipment is taken on site.

c. The drilling contractor should always act with competent engineering advice and assess the general hazards which may arise during construction and drilling due to the nature of the ground, the existence of high water, gas or oil pressures in the strata, surface and underground installations and services.

d. The site should be inspected before rig entry to find a safe approach route to the proposed drilling position. Some guidance may be required for winching or lowering rigs on steep slopes and in setting up in marshy or other soft areas.

e. It should be ascertained that the load bearing quality of the proposed site is adequate for safe working conditions. Hazardous situations such as old rock fill, unstable material, surface soils on sloping rock surfaces, under dangerous banks or quarry sides and on quarry edges should be avoided.

f. A clear access to and from the site should be provided with good visibility in all directions. If this is not possible, traffic leaving the site should be controlled by a person nominated for that purpose.

g. The working area should be suitably prepared and where necessary levelled, surfaced and drained. Means should be provided to trap any escape of petrol, diesel fuel or oil which might leak into the water courses, fields or public drains, before it leaves the site.

h. The site should be adequately fenced and warning notices posted, with separate fencing and warning notices being provided for any mud or slurry pits.

i. Where working platforms are required to support men, equipment and/or materials, the platform should be properly constructed. It should be of adequate dimensions, and if over 2 metres above ground, should have guard rails and tow boards so placed as to prevent falls of persons or articles from the platform. Similar guard rails and tow boards may be considered desirable on platforms constructed at lesser heights in some circumstances. The platform construction and stability should be checked weekly for defects.

1.5.4 SETTING UP

a. The site must be kept in a well organised tidy state and clear of all debris and extraneous material.

b. It is preferable for acoustic barriers to be constructed of non-flammable material.

c. It should be ensured that all relevant machine guards have been installed before starting up any machine.

d. Bulk stocks of fuel, oil and gas cylinders should be stored in a designated compound remote from the immediate working area.

e. Rods, Casings etc. should be neatly stacked, preferably on appropriate racks and maintained in a clean condition.

f. Threads and connectors should be regularly cleaned and greased, and preferably protected with thread protectors.

g. Tools and materials should be laid out according to requirements and in order of use.

1.5.5 DRILLING OPERATIONS - GENERAL

a. Drilling may entail the employment of some personnel inexperienced in this class of work. In such circumstances, particular care should be taken to explain and enforce safety precautions, and teach practice in the handling and use of equipment. It is important that safe working systems of work are adhered to by all personnel.

b. Inexperienced men should always remain under expert supervision.

c. At the commencement of each shift the incoming crew should make certain that the equipment is in a useable and safe condition. Unsafe conditions and any significant change in operating conditions should be reported in the driller's log book and any action taken thereon should also be logged.

d. Each operation must have its set routine, each team member knowing exactly what part he is to play.

e. Under no circumstances must a rig be operated by one man.

f. High noise level areas should be identified and hearing protection worn where necessary.

g. Where engine noise or other sounds prohibit verbal communication, a clear set of signals which are clearly understood and known by each team member should be used. This will also apply when ear defenders are worn.

h. It should be ensured that the winch operator has a clear view of men operating equipment at all times.

1.5.6 DRILLING OPERATIONS – CABLE PERCUSSION

a. A firm and level working surface should be established for the erection of the rig using timber sleepers where necessary. Mast guys, if applicable, should be correctly positioned and securely anchored, properly tensioned and frequently checked.

b. The equipment should always be operated in a safe manner and in accordance with the manufacturer's instructions.

c. Cable tools which are not in use should be laid down horizontally on timber grillage and should not be left in an upright position resting against the derrick.

d. The correct tool should always be used for the operation being undertaken.

e. Personnel should keep clear of suspended equipment and use a rope, strap or bail hook to swing tools away from the borehole. They should never look down the borehole beneath a suspended tool.

f. When the drive clamps are suspended or in use the operator should not place his hand on the drive head. When casing is being driven the drive clamps should not be suspended above the operator's head. Short lengths of casing can be used for this operation.

g. Tools should not be held in suspension be means of only the hand or foot control when personnel are changing or working on them.

h. The winch operation should be in accordance with the manufacturer's instructions, and should not be overloaded when pulling casing. When additional force is required proper jacking equipment with positive connections between jack head and casing should be employed, or an appropriate casing jar.

i. Casing tubes and tool joints should always be screwed well home in order to avoid damage to the threads and to prevent parting.

j. When driving casing, personnel should not place their fingers in tommy bar holes or over the lip of the casing.

k. All worn or splintered drive heads, drilling tools, sinker bars. Etc. should be replaced. Crushed, bruised or damaged wirelines should be removed immediately.

l. Sheave Wheels shafts and pins should be checked daily, kept well lubricated and replaced when worn.

m. Personnel should be alert for indications of broken strands of wire ropes and of shackles becoming undone.

n. Cuttings or spoil at the hole collar should not be cleared by hand or any tool unless the rig is in neutral and the clutch disengaged.

o. Slurry pits should be positioned so that they can be reached safely and easily by the bailer/shell without danger to the drill crew or undue stress on the bailing line. They should not be so close to the rig as to undermine the rig grillages.

1.5.7 PLANT MAINTENANCE

a. Plant, machinery and structures should be inspected at regular intervals in accordance with the manufacturer's recommendations. In the case of plant which is subject to corrosion, steps should be taken to effect repairs before corrosion reaches dangerous limits.

b. A planned preventative maintenance system covering shift, daily, weekly and periodic times should be established for the different types of machine used. This should include the inspection of all pulleys, drum surfaces and ropes, and should stipulate their regular cleaning and lubrication. The system should include a three-part sequence of inspection, thorough examination and testing. Results of each stage are to be recorded and signed.

c. Cleaning, repair, maintenance, oiling or greasing of machines or the topping up of fuel tanks should not be carried out whilst a machine is operating.

d. If inspection involves the running of a petrol or diesel engine in an enclosed space, all doors and windows to the workshop should be opened and even then, the engine should only be run intermittently to avoid a dangerous build-up of fumes.

e. All plant should be kept clean by the regular removal of mud and dirt and of snow and ice in winter, if applicable.

f. When major dismantling of components is necessary, the correct lifting equipment should always be used and it should be ensured that struts and chocks are strategically placed as the process continues.

g. The ignition key should always be removed, and a notice placed in such a prominent position that it cannot be missed, if it is necessary to work underneath a machine, or to leave it in an incomplete unsafe state.

h. Moving parts of machinery are to be guarded where possible and such guards should be in position when machinery is in normal operation. Guards should not be removed except as required for maintenance purposes, in which case the machine should be immobilised.

i. Lifting machines and tackle should be inspected and tested at set intervals and certified for the maximum permissible working loads, and these loads should not be exceeded. Following any major repair, they should be re-certified before being returned into service. The owner/operator should be aware of current legislation in force in their own country and comply with all regulations regarding re-testing of equipment.

j. Electrical installations should be effectively earthed.

k. Electrically operated hand tools, together with leads and earth wires, should be inspected at regular intervals to ensure that they have been maintained in good order, and such inspections should be recorded.

l. Trailing cables, except for hand-lamps and small portable tools should be of a standard equal to BS 708. Pliable armoured cables are preferred.

m. When high pressure grease guns are used, protective gloves should always be worn and care taken to avoid injecting grease under the skin.

n. Hoses used for steam cleaning should be of the type made for steam service. The metal nozzle should always be securely clamped to the hose and maintained in serviceable condition.

o. A flammable liquid within the classification of Class 'A' or Class 'B' petroleum should not be used for cleaning purposes, except in very special circumstances, and then by written permission only.

p. Loose boards and materials not in use should be removed from the derrick floor.

q. Steps and guard rails, where applicable, should be maintained in good condition. If it is necessary to remove them temporarily during installation of the machinery, they should be replaced without delay when finished.

r. To eliminate slipping hazards, drilling rig floors, etc. should be kept as free of mud and oil as practicable. Better footing is provided if the floor is washed while the next stand of pipe is being picked up. Non-skid materials are useful in some areas to prevent slipping.

1.5.8 SITE ABANDONMENT

a. Every uncompleted borehole should be fenced or temporarily capped in a safe manner when the rig has moved off and until the hole is finally capped.

b. Unless a borehole is required to be kept open for some specific purpose, it should be infilled, consolidated and capped in such a manner that there will be no subsequent depression at ground surface due to settlement of the infill material.

c. Surface standpipe should be withdrawn or cut at least one metre below ground level prior to infilling the borehole.

d. Capping pads should be placed at least one metre below ground level.

e. Mud and slurry pits should remain adequately fenced and signposted until emptied, backfilled and consolidated. Any impervious membrane should be removed prior to restoration.

f. The site should be left in a safe, clean and tidy state, with all gates and fences left as found.

1.5.9 TRAINING

a. The most important factor of all on site safety is the full education and practical technical training of all drill crew members in all aspects of drilling and associated operations.

b. Such training should include not only basic safety precautions, but also a thorough understanding of the correct use of all plant, equipment and tools.

c. In addition, knowledge should be given of the forces of both energy and mass which the crew control through the medium of the drill rig.

d. The prime concept of this training is to teach each crew member to do his own job efficiently and safely, and to so work with the other members of the crew that good and safe team work becomes instinctive.

e. This not only results in steady and safe progress, but secures higher production.

f. All training whatever the size of the organisation, should be formally programmed throughout the number of stages required by the personnel concerned. Each step in the training module or syllabus should be monitored by a fully trained instructor, and duly recorded towards the eventual certification of the trained crew member upon completion of the course concerned.

g. Training should be so presented that the stimulation of personal interest and the known attainment of craft and skill achievement is a main aim and result. Such training therefore should be initiated and encouraged by both management and supervisory staff.

h. Emphasis should be made on the value of efficient teamwork towards the goal of high and safe production.

i. It cannot be too strongly stressed that the operatives' involvement and outlook is dependent upon the quality and support of the employer.

j. The responsibility for all aspects of site safety rest with all levels of management.

1.5.10 WELFARE AND PERSONAL PROTECTION

a. The Health and Safety at Work Act 1974 (United Kingdom) requires every employee, while at work, to take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions at work. In this regard, personal and site safety and hygiene are most important.

b. Adequate and suitable protective clothing should be provided for any person employed who, due to the nature of his work, is required to continue working in the open air during rain, snow, sleet or hail.

c. Adequate accommodation for personnel to take shelter during bad weather, for the storage, drying and changing of clothing and for taking of meals should be available. Such accommodation should include the facility for boiling water, heating food and the provision of washing facilities to permit personal hygiene. Personnel should be encouraged to wash before partaking of food.

d. Washing and kitchen waste water should be discharged into a pit or sump dug into the ground remote from ditches and water courses.

e. Empty tin cans, bottles, plastic containers, drums and scrap metal, wire rope etc., should be placed in containers for transport to recognised waste disposal sites.

f. Suitably ventilated chemical toilets housed to provide privacy, should be available. These should be regularly serviced and contents disposed of in accordance with manufacturer's instructions. Personnel should be encouraged to wash after using these facilities.

g. Potable/drinking water should be available and containers clearly marked as such to distinguish from non-potable/non-drinkable water.

h. Oil saturated clothing is a fire risk, and also a health risk in that it irritates the skin. They should be changed as soon as possible.

i. Advice should be sought from the local water authority and their medical officer of health prior to working in sewers or on waste disposal sites. When working in these situations rubbing of the nose or mouth with the hands should be avoided. On completion of the work, hands and forearms should be thoroughly washed with soap and clean water with an added disinfectant. Any clothing or boots that have become contaminated should be washed, cleaned or disinfected. Any cut, scratch or abrasion should be cleaned, treated with antiseptic and completely covered until quite healed.

j. The possibility of existing excavations transmitting bacteria carrying liquids into a working area should not be overlooked.

k. It is advisable that drilling crews should receive regular anti-tetanus injections, and always carry their anti-tetanus injection card with them.

l. Relatively harmless materials can cause irritation leading to more harmful effects by repeated or prolonged exposure so that every effort should be made to avoid inhaling dust, fumes or smoke. Should such conditions have to be endured as a temporary measure, suitable protective equipment should be used.

m. Similarly, prolonged or repeated contact with the skin of certain substances, chemicals, oils or other fluids can be harmful. Under these circumstances, protective gloves/clothing should be worn, and/or barrier creams used. Any such skin contacts should be washed before eating food, and this should not be consumed in the working or contaminated area.

n. Personnel should be fully protected against any hazard likely to be incurred in carrying out their work. Protective clothing and equipment should therefore be issued, maintained in good order and replaced when necessary.

o. Rig personnel should wear only close-fitting clothing, preferably distinctly coloured overalls. Clothing should be kept clean by frequent washing, and each crew member should have a clean change of work clothes on location at all times. Particular care should be taken to ensure that drawstrings to hoods or other items of clothing are not left dangling so as to become entangled in any moving parts.

p. If overalls are not worn, long-sleeved shirts with tails tucked in will provide protection against sunburn, insect bites, scratches, hazardous chemicals and flash burns.

q. Safety helmets must be worn by members of the drilling crew and visitors to the site. Safety boots or safety wellingtons should also be worn.

r. When working on or adjacent to the public highway, a top coat, jerkin or waistcoat, with fluorescent markings must be worn at all times.

s. The use of gloves whenever practicable is recommended. Gloves prevent minor injuries when employees are handling rough materials or skin irritants. Only short, tight fitting gloves should be worn. Gauntlets may become caught in the machinery and workers may be pulled into moving machinery if they wear them.

t. Hairnets should be worn by persons with dangerously long hair. Loose clothing, i.e. trailing scarves, ties etc. should be avoided, especially when working near rotating machinery.

u. Rig personnel should never wear finger rings or bracelets while working.

v. Eye protection is of the utmost importance. An eye injury, no matter how slight, should receive prompt medical attention. Even a slight eye injury may lead to serious complications.

w. The correct eye protection should be provided and should be maintained in good condition on each drilling site. Employees should wear approved safety glasses or goggles when chipping, grinding, scraping, buffing, breaking or cutting any metal or material that involves a flying chip hazard.

x. Operators who wear contact lenses should wear eye protection and should always be aware of the problems posed by contact lenses when attempting prompt emergency treatment following the introduction of foreign material into the eye.

y. Splash proof chemical goggles or face-shields should be used when handling potentially hazardous or injurious chemical liquids, powders or vapours such as cement, chemicals, chemical cleaning solutions, creosoted material, molten metal, asphalt or bitumastic compounds. Goggles also should be worn by persons near operations which require the use of safety goggles by the operator.

1.5.11 WIRE ROPES - GENERAL SAFETY AND MAINTENANCE

a. Regular inspection of ropes in service is essential if high standards of safety are to be ensured, and the relevant test certificate must be obtained and available.

b. All running ropes in continuous service should be visually inspected once every working day by an authorised person.

c. A thorough inspection of all ropes in use should be made at least once a month and a full written, dated and signed report of rope condition kept on file and readily available.

d. Any deterioration resulting in appreciable loss of original strength, such as described below, should be carefully noted and the rope should not be used if any of the following situations are present:

i) Reduction of rope diameter below nominal diameter due to loss of core support, internal or external corrosion or wear of outside wires.

ii) In any length of diameters, the total number of visible broken wires exceeds five percent of the total number of wires in the rope.

iii) Corroded or broken wires at end-connections.

iv) Corroded, cracked, bent, worn or improperly applied end-connections.

v) Severe kinking, crushing, cutting or under stranding.

vi) Heavy wear and/or broken wires may occur in sections in contact with equaliser sheaves, or other sheaves where rope travel is limited, or with saddles. Particular care should be taken to inspect ropes at these locations.

vii) All rope that has been idle for a period of a month or more due to shutdown should be given a thorough inspection before it is placed in service. This inspection should be for all types of deterioration and should be performed by an authorised person whose approval should be required before further use of the rope.

viii) Particular care should be taken in the inspection of non-rotation rope.

ix) Wire rope removed from service due to defects should be plainly marked or identified as being unfit for further use on load carrying devices.

e. Upon receipt of wire ropes, whether they arrive in coil form or on reels, it is advisable to examine, and if necessary remove, the outer protective wrapping. This may have become wet during transit and, if left on the rope local corrosion will appear in course of time. Ropes should be stored in a dry atmosphere and preferably off the floor, on well seasoned timber.

f. Rope delivered in reel form should have the reel jacked up to turn freely, so that the rope can be carried straight away from the reel. Provision should be made to stop reel rotation by using a braking device, however simple.

g. When rope is delivered in coil form, it should be rolled along a smooth surface, like a hoop, away from the end of the rope, and protected from unnecessary bending and abrasion.

h. When rope cannot be stretched out straight, it should be arranged in a long narrow “U” or series of “U’s” with as wide a radius for the turn of the “U” as possible.

i. When handling wire rope, it should be manipulated so that its natural twisting action will not cause it to kink.

j. A replacement rope must be of the same type and specification as the original fitted to the rig by the manufacturer, and of the correct safe working load.

k. Care should be taken when installing ropes on winding drums to ensure that there is even tension of the new rope being pulled round the system, that sharp bends are avoided and that the rope is kept clear of dirt and abrasive materials.

l. Rope should be kept tightly and evenly wound on the drums.

m. When the rope is feeding onto the drum it should not be touched by hand.

n. In order to prevent crushing the rope where a drum divider is used, there should not be more than four turns on the working section when the tool is at the deepest point.

o. Overruns should be avoided by correct winch operation.

p. The rope should be firmly fastened in the drum with set-screws, or a suitable clamp, and three full turns of the rope should be kept on the drum at all times.

q. Every rope should be thoroughly lubricated with the correct wire rope dressing as it is installed, and kept similarly coated throughout its life.

r. When equipment using wire rope is kept in dead storage for any length of time, the rope should not be left on the equipment.

s. Connections, fittings, fastenings, parts etc. used in conjunction with cables and ropes should be of good quality and of proper size and strength and should be installed in accordance with the recommendation of the manufacturer.

t. Socketing, splicing and sizing of wire rope should be performed by qualified persons.

u. All eye splices should contain the proper size of rope thimble.

v. When wire rope clips are used, the base of the clip must bear on the “live” end of the rope - the “live” end being the free-running portion of the rope. The “U” section of the clip bears on the dead end of termination fold of the rope. Failure to follow this procedure could cause the “U” bolt to kink or cut the live end of the anchor and cause failure.

w. Spacing of the clips, or “U” Bolts, is also important. They should be installed about six rope diameters apart, and tightened securely before the rope is placed in tension - and tightened again after the rope is put into use. The pulling on the rope can cause a slight reduction in its diameter with a resultant loosening of the clips.

x. When a wedge socket-type of fastening is used, the dead of shortened end of the rope should be clipped with a U-bolt or otherwise made secure against loosening.

y. Winch ropes should not be lopped, knotted, or kinked around themselves or any other object except suitably designed “D” etc.

z. Lifting hooks or shackles should be attached to the winch rope via a swivel connection which can operate under maximum load.

aa. Whenever possible, new wire rope should be run under light load for a short period after it has been installed in order to adjust the rope to working conditions.

bb. Sudden, severe stresses are damaging to wire rope and such applications should be reduced to a minimum. A jerk line may be rigged and clamped to the drilling line when it is necessary to have considerable jarring in one place.

cc. Experience has indicated that wear increases with speed: economy results from moderately increasing the load and diminishing the speed.

dd. All winch ropes should be checked from time to time for excessive wear and be replaced when necessary.

ee. Personnel should be kept a safe distance from lines being used for hoisting and pulling. They should never straddle them of reach across them, since serious injuries can result from the whiplash of a line that either breaks or is loosened suddenly. When straightening cable of winding it onto a hoist drum, the operator should be constantly alert at the controls.

ff. If rope is used to haul equipment to the working areas, a straight pull should be maintained from the winch through the pulley to the equipment.

gg. Protective gloves should be used when handling wire ropes.

1.6 RECOMMENDATIONS

1. **WHEN OPERATING RIG, WEAR ADEQUATE SAFETY CLOTHING.**

2. **DO NOT CRANK THE ENGINE FOR MORE THAN 30 SECONDS. ALLOW THE ELECTRIC STARTING MOTOR TO COOL FOR TWO MINUTES BEFORE CRANKING THE ENGINE AGAIN.**

3. **ALWAYS CHECK ALL CONTROLS ARE IN NEUTRAL WHEN STARTING UP.**

4. **ALWAYS ENSURE HANDBRAKE IS ON BEFORE RAISING LEVELLING RAMS.**

5. **ATTEMPT AT ALL TIMES TO ENSURE PERFECTLY CLEAN HYDRAULIC OIL IS MAINTAINED.**

6. **WASH OFF, AS SOON AS POSSIBLE, ANY HYDRAULIC OIL THAT GETS INTO CONTACT WITH SKIN.**

7. **INSPECT WIRELINES AND HOSES FOR WEAR DAILY.**

8. **ALWAYS REPLACE WIRELINES AT THE FIRST SIGN OF WEAR. THE SIGNS OF WEAR ARE FLATTENING, OR BROKEN STRANDS.**

1.7 WARNINGS

1. **DO NOT ATTEMPT TO OPERATE THE RIG ALONE. ROTARY DRILLING RIGS REQUIRE AT LEAST A TWO MAN CREW FOR SAFE OPERATION.**

2. **BREATHING DUST IS DANGEROUS TO HEALTH. OPERATE IN A WELL VENTILATED PLACE AND USE APPROPRIATE EXTRACTION EQUIPMENT OR A DAMP CLOTH TO REMOVE DUST. DAMPEN ALL DUST. DISPOSE OF WASTE IN HEAVY GAUGE PLASTIC SACKS IN ACCORDANCE WITH LEGISLATIVE REQUIREMENTS.**

3. **THIS RIG IS FITTED WITH AN ALTERNATOR. DO NOT DISCONNECT BATTERIES WHEN ENGINE IS RUNNING. DO NOT TURN IGNITION KEY TO '0' POSITION ON SWITCH WHILE THE ENGINE IS RUNNING. IF ANY ARC WELDING TAKES PLACE ON THE RIG DISCONNECT BOTH BATTERY AND ALTERNATOR. WHEN BRAZING, SOLDERING OR WELDING, IT IS ESSENTIAL THAT ANY EXCESSIVE HEAT SOURCE IS KEPT AWAY FROM THE VICINITY OF THE ALTERNATOR AND ANY NYLON PIPING OR RUBBER HOSE. FAILURE TO COMPLY WITH THESE WARNING WILL LEAD TO COMPONENT DAMAGE AND MAY CAUSE INJURY.**

4. **THE TRAILER ON WHICH THE RIG IS MOUNTED IS DESIGNED WITH A LOAD CARRYING CAPACITY FOR THE RIG ONLY, UNLESS OTHERWISE SPECIFICALLY STATED. DO NOT ADD PLATFORMS ETC. FOR CARRYING ADDITIONAL ITEMS AS THIS WILL OVERLOAD THE TRAILER, CONTRAVENING THE ROAD TRAFFIC CONSTRUCTION AND USE REGULATIONS IN THE UNITED KINGDOM.**

5. **ENGINE EXHAUST EXTENSION PIPES ARE A FIRE HAZARD AND MUST NOT BE FITTED TO THE MACHINE.**

6. **BEFORE STARTING/SHUTTING DOWN THE ENGINE (EXCEPT IN AN EMERGENCY), ENSURE THAT ALL CONTROLS ARE IN THE NEUTRAL/OFF/MINIMUM POSITION.**

7. **ENSURE ENDS OF HYDRAULIC HOSES ARE PLUGGED WHEN REMOVED FROM HYDRAULIC MOTORS.**

8. **DO NOT ATTEMPT TO MOVE RIG WITH MAST IN RIGGED UP POSITION.**

9. **DO NOT MIX MAKES OF HYDRAULIC OIL. SEE LIST OF RECOMMENDED OILS.**

10. **DO NOT RAISE MAST ADJACENT TO OR INTO CONTACT WITH OVERHEAD POWER CABLES.**

11. **DO NOT WORK UNDER LOAD SUSPENDED ON WINCH LINE.**

12. **AT THE END OF EVERY OPERATION DO NOT LEAVE CONTROLS IN ENGAGED POSTIONS BUT ALWAYS RETURN THEM TO THEIR NEUTRAL/MINIMUM/OFF POSITION.**

13. **DO NOT FORGET TO SWITCH OFF THE BATTERY ISOLATOR IF LEAVING THE RIG.**

SECTION 2

TECHNICAL DATA

SECTION 2 – TECHNICAL DATA

It is imperative that the rig serial number is quoted in any correspondence or spares requisition.

2.1 RIG SERIAL NUMBER - DDUKE691100543009

Stamped on a plate which is riveted to the Chassis Rear Member.

2.2 GENERAL DATA

2.2.1 RIG DIMENSIONS – TRAILER VERSION

Total Gross Weight	2940kg
Max. Length (Mast Erected)	7.107m
Max. Height (Mast Erected)	6.364m
Max. Useable Height (Mast Erected)	5.500m
Min. Length (Mast Erected)	6.330m
Min. Height (Mast Erected)	4.915m
Min. Useable Height (Mast Erected)	4.000m
Max. Width (Mast Erected)	2.204m
Travelling Length	4.476m
Travelling Width	1.870m
Travelling Height	2.056m

2.2.2 RIG DIMENSIONS – TRACKED VERSION

Total Gross Weight	3417kg
Max. Length (Mast Erected)	5.646m
Max. Height (Mast Erected)	6.364m
Max. Useable Height (Mast Erected)	5.673m
Min. Length (Mast Erected)	4.869m
Min. Height (Mast Erected)	4.915m
Min. Useable Height (Mast Erected)	4.224m
Max. Width (Mast Erected)	2.204m
Travelling Length	4.092m
Travelling Width	1.850m
Travelling Height	2.095m

2.2.3 DRILLING DEPTHS AND DIAMETERS

Drilling Depth	75m
Drilling Diameter	100mm to 460mm

2.2.4 POWER UNIT

Perkins 1.5L 403D-15 Water cooled diesel engine
Continuous (32 bhp)

Output Torque	94.4Nm
Optimum Working Engine Speed	1500-2000rpm
Fuel Tank Capacity	44 Litres (Diesel)

2.2.5 COMPRESSOR

Dynaset HK 450/8 – 14

Maximum Pressure	8bar (116psi)
Maximum Flow Rate	450 l/min (15.9cfm)

2.2.6 HYDRAULIC SYSTEM

Oil Capacity	130 Litres approx. ISO 46 Compliant
Oil Type	Biodegradable Oil: Holbein NWG 46

2.2.7 MAST

Maximum Derrick SWL	6000 Kg
Max Working Height	5.5m
Min Working Height	4m

2.2.8 STABILISING OR LEVELLING JACKS

Four levelling jacks, one at each corner of rig

2.2.9 MAIN FEE FALL WINCH

Drum Capacity 90m of 16mm wireline

	BARE DRUM	FULL DRUM	MAX PULL
HIGH SPEED	82m/min	154m/min	1490kg
LOW SPEED	40m/min	82m/min	3000kg

2.2.10 TOOLING WINCH

Dinamic Oil NP05

Drum Capacity	20m of 8mm wireline
Max Line Speed	38m/min
Max Pullback	500kg
Oil Capacity	0.6 Litres. ISO 46 Compliant

2.2.11 TYRES

Tyre Type	185/70 R13	
Wheel Nuts – Torque	140.12 Ft Lb	190 Nm
Max. Tyre Pressure (Cold)	85 psi	5.86 Bar

2.2.12 TOWING WEIGHTS – TRAILER VERSION

Total Mass	2940kg
Axle 1 (Max.)	1750kg
Axle 2 (Max.)	1750kg

2.2.13 FINE FEED BRAKE CONTROL

Fine Feed Brake Control Working Load Limit (WLL)	500kg

2.2.14 SPT HAMMER ASSEMBLY (OPTIONAL EXTRA)

Total Mass	197kg

SECTION 3

OPERATING INSTRUCTIONS

SECTION 3 – OPERATING INSTRUCTIONS

INTRODUCTORY NOTES

The **Dando Duke** Drilling Rig is a cable percussion drilling rig available in trailer and track mounted versions incorporating a range of proprietary items. Operating and Maintenance procedures these items are supplied with the rig and should be studied before using and setting the rig to work.

3.1 ACCEPTANCE OF RIG

On taking delivery of a new rig, generally check it over to see that no material damage has occurred during transit. Remove all loose items, unpack cases etc., and check the consignment against the Delivery Note or Packing List.

Rigs are normally dispatched completely assembled and in full working order. For rigs dis-assembled in any form see separate instructions.

Before using the rig, it is strongly recommended that the operator becomes completely familiar with the layout of the rig and controls in conjunction with these instructions so that the general operational procedure and basic mechanism of the rig are clearly understood. These instructions cover the standard basic rig and controls, but may differ if customer special requirements have been made to the system, in which event these controls/functions will be labelled accordingly.

3.2 TRANSPORT

The rig is available in both trailer and track mounted versions. The vehicle used to tow the trailer version should be of sufficient size and power for this function. The tracked version of the rig is fitted with a 2 speed tracking motor with radio remote control tracking.

However, the operator should be mindful of any legislation in force in whatever E.C. Country the rig is being used, and comply fully with those regulations.

The trailer version of the rig is supplied with a towing hitch with overrun braking system which complies with current E.C. regulations.

When the rig is parked, the parking brake should be engaged by pulling the handbrake.

The operator's attention is drawn to the Guidance Notes on Safety (Section 1) relating to general and specific areas to be noted with regard to transport and towing of the drilling rig.

3.3 CONTROLS

INTRODUCTION

Please refer to following diagrams for the position and general layout of the rig control panels.

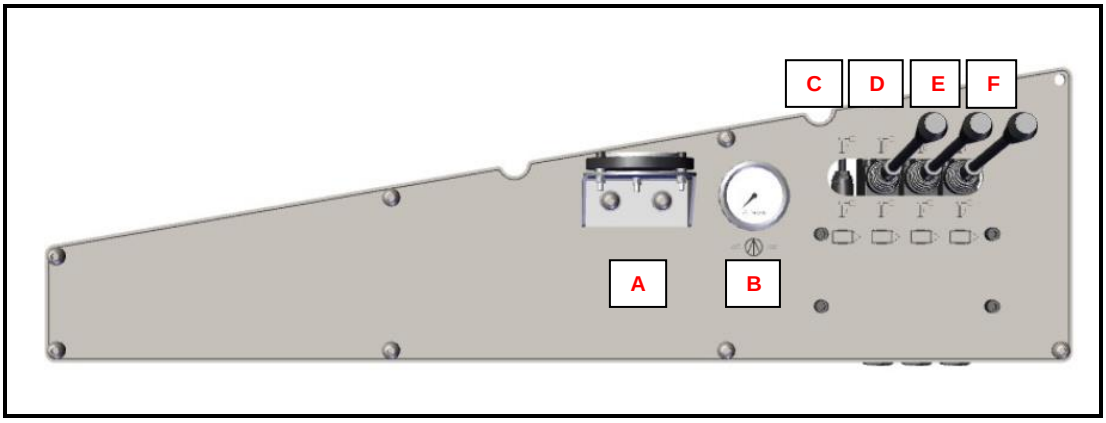


Figure 3.1

TOP CONTROL PANEL

A. Circular Level
B. Receiver Tank Air Pressure Gauge

C. Front Right Jack Control
D. Front Left Jack Control
E. Rear Left Jack Control
F. Rear Right Jack Control

Figure 3.2

PTO CONTROL PANEL

A. Fuel Gauge
B. Auxiliary Function Oil Pressure Gauge
C. Engine Oil Pressure Warning Indicator
D. Engine Water Temperature Warning Indicator
E. Key Switch
F. Tachometer
G. 12V DC Cigarette Lighter Socket
H. Recoil Air Line Control

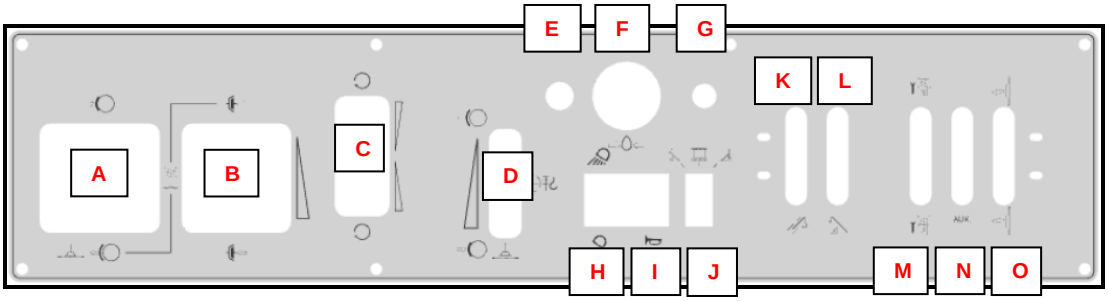


Figure 3.3

BOTTOM CONTROL PANEL

Free Spool Winch:

A. Holding Brake Control
B. Clutch Control
C. Hoisting Reel Speed Control

D. Fine Feed Brake Control

E. Emergency Stop
F. Hydraulic Oil Pressure Gauge
G. Engine Throttle Control

H. Work Light Switch
I. Horn Switch
J. Mode Switch - Rigging/Tracking/Drilling

K. Mast Extension Control
L. Mast Raising Control
M. Tooling Winch Control
N. Auxiliary Circuit Control
O. SPT Stowing Winch Control

3.3.1 FREE SPOOL WINCH BRAKE

The Holding Brake is controlled by a Brake Lever (Control A, Figure 3.3).

To engage the brake, the Brake Lever is pushed away from the operator. This lever is spring operated and when released will engage the brake.

To disengage the brake, the Brake Lever is pulled towards the operator.

There is a brake safety latch situated on the lever. This will locate in the recess to lock the brake on.

It is important that the brake control be left in the locked position when the machine is not being used, or when tools are being handled in the working area.

The attention of the operator is drawn to the Guidance Notes of Safety – Section 1.5.6 - Drilling Operations - Cable Percussion, relating to general and specific areas to be noted regarding the safe operation of the drilling rig.

3.3.2 FREE SPOOL WINCH CLUTCH

The Free Spool Winch Clutch is controlled by a Clutch Lever (Control B, Figure 3.3).

To disengage the clutch, the Clutch Lever is pushed away from the operator.

To engage the clutch, the Clutch Lever is pulled towards the operator.

3.3.3 ENGINE

Please refer to the instructions in the Engine Manufacturer's Handbook provided.

The engine speed should be adjusted to ideal idling speed whenever the rig is started up or shut down.

3.3.4 FINE FEED BRAKE CONTROL

The Fine Feed brake is controlled by a Brake Lever (Control D, Figure 3.3) with a Working Load Limit (WLL) of 500kg. Dando Drilling will not be responsible for any misuse above this Working Load Limit.

3.4 ASSEMBLY OF RIG

3.4.1 SITE PREPARATION

Before moving the drilling rig to the proposed drilling position, the drilling site should be inspected and prepared, by removing debris and any obstructions if possible.

In selecting a suitable position for the rig, it is essential there is sufficient room for the deployment and erection of the mast assembly including support legs, spreader bar and sidestays. The ground on which the drill is to be positioned must be reasonably level and firm.

The attention of the operator of the equipment is drawn to the Guidance Notes on Safety (Section 1) relating to general and specific areas to be noted with regard to site preparation and site safety.

3.4.2 ERECTING PROCEDURE

1. Apply the parking brake. Use chocks under the wheels if required. Unhitch and remove the towing vehicle. Remove any mast weights, lower crossbar & side stays, any tools or equipment from the derrick.

2. Remove spreader bar pin, unlock clamp bracket & remove spreader bar (Figure 3.4), stay bar pins & stay bars (Figure 3.5) and lower leg pins (Figure 3.6).

FIGURE 3.4

FIGURE 3.5

FIGURE 3.6

3. Unhook BOTH the main and tooling winch hooks from their stowage positions (Figure 3.7). Extend main and tooling winch cables at least 2m.

FIGURE 3.7

4. Remove the SPT Auto Hammer upper pins from the mounts on the mast if the SPT Auto Hammer is required (Figure 3.8).

FIGURE 3.8

5. Set the mode switch to rigging (Control J, Figure 3.3) and level the rig using the levelling jacks, (Controls A-D, Figure 3.1). Suitable timbers or pads can be used to protect the ground or provide more stability on soft surfaces.

6. Extend the inner legs and pin through the outer legs to secure the inner legs in their drilling position (Figure 3.9).

FIGURE 3.9

7. Extend the mast boom fully (Figure 3.10), (Control K, Figure 3.3).

FIGURE 3.10

8. Raise the mast to the vertical position (Figure 3.11), (Control L, Figure 3.3).

FIGURE 3.11

9. Continue to raise the mast into the drilling position (15 degrees forward) whilst guiding the legs out to approximately 3m from the front of the rig (Figure 3.12).

FIGURE 3.12

10. Retract the mast boom until both feet touch the floor, note that if drilling on soft or uneven terrain wooden boards may be placed underneath the feet to spread the load and level the rig.

11. Raise the stay bars to the drilling position and pin (Figure 3.13 & Figure 3.14).


FIGURE 3.13

FIGURE 3.14

12. Place the spreader bar between legs and pin (Figure 3.15).

FIGURE 3.15

13. Check all pins are secured with linchpins, all feet are securely in contact with the ground or supporting timbers, the mast is level & positioned central to the rig chassis. Wooden beams may be used to help level the mast if required. The rig is now fully erected and ready for drilling (Figure 3.16).

FIGURE 3.16

3.4.3 TAKE-DOWN PROCEDURE

1. Unpin and remove the spreader bar (Figure 3.17).

FIGURE 3.17

2. Unpin and remove the stay bars (Figure 3.18 & Figure 3.19).

FIGURE 3.18

FIGURE 3.19

3. Fully extend the mast boom (Control K, Figure 3.3), be aware that the legs will move towards the rig (Figure 3.20).

FIGURE 3.20

4. Bring the mast back to the vertical position (Control L, Figure 3.3) whilst guiding the legs into their stowage position (Figure 3.21).

FIGURE 3.21

5. Continue lowering the mast until it is securely seated in the headache post (Figure 3.22).

FIGURE 3.22

6. Retract the mast boom fully (Control K, Figure 3.3).

7. Remove the pins connecting leg inners and outers. Retract the inner legs and pin the inner legs in their stowed position (Figure 3.23).

FIGURE 3.23

8. Retract the levelling jacks (Controls A-D, Figure 3.1).

9. Fit the side stays and spreader bar in their stowing positions. Pin side stays and spreader bar securely.

10. Hook BOTH the main and tooling winch hooks to their stowage positions.

11. Replace the SPT Auto Hammer upper pins to the mounts on the mast if the SPT Auto Hammer was used.

12. Hitch the drilling rig to the towing vehicle. This completes the Take-Down procedure.

3.5 SPT AUTO HAMMER DEPLOYMENT

3.5.1 Deployment Procedure

1. To deploy the SPT hammer, set the mode switch to drilling (Control J, Figure 3.3).

2. Attach the SPT Auto Hammer extension cable to the tooling winch hook (Figure 3.24) and raise tooling winch to take out slack (Control M, Figure 3.3).

FIGURE 3.24

3. **Caution: The SPT Auto Hammer must be supported with the SPT Stowage Winch on removal of pins to prevent swing out.**

4. Raise the tooling winch (Control M, Figure 3.3) until the locking bracket fabrication lugs have cleared the two top stowage fabrication slots (Figure 3.25).

FIGURE 3.25

5. Wind out the SPT stowing winch (Control O, Figure 3.3).

6. Lower the SPT Auto Hammer to the desired height using the tooling winch (Control M, Figure 3.3). Disconnect the stowing winch strap from the hook on the SPT Auto Hammer.

7. Connect the extension hoses to the motor quick connect fittings. Ensure the quick connections are twisted into the lock position.

8. Connect the other ends of the extension hoses to the auxillary power take off (PTO) of the rig. (Use the top two outputs on the PTO as the lower one is case drain only). Ensure that the quick connections are twisted into the lock position.

9. The SPT Auto Hammer is now ready for operation. The PTO lever on the main console (Control H, Figure 3.2) controls the SPT Auto Hammer motor. Height can be adjusted using the tooling winch.

3.5.2 Stowing Procedure

1. Connect the stowing winch strap to the hook on the SPT Auto Hammer (Figure 3.26).

FIGURE 3.26

2. To stow the SPT Auto Hammer wind the winch up using the tooling winch (Control M, Figure 3.3) until the locking bracket fabrication lugs are over the top stowage fabrication slots. (The tooling winch can be adjusted to get the lugs close to the slots. See 3.27 for recommended height, indicated by red line).

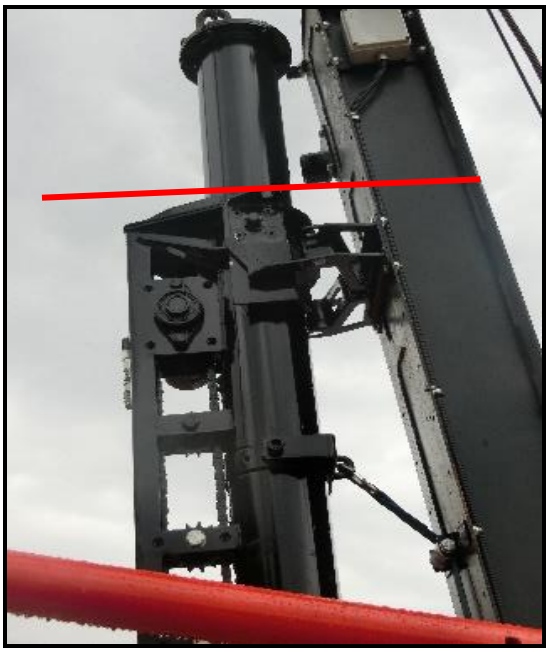


FIGURE 3.27

3. Lower the tooling winch until the locking bracket fabrication lugs on the SPT Auto Hammer locate in the top stowage fabrication slots of the mast. The tool winch should be lowered until the top section of the auto hammer is resting against the mast and the tool winch cable is slack (Figure 3.28).

FIGURE 3.28

4. Wind in the stowing winch towards the mast until the SPT Auto Hammer locates into the bottom stowage bracket. Fasten the winch strap using the ratchet (Figure 3.29). This completes the stowing procedure.

FIGURE 3.29

3.6 SPT HAMMER OPERATION

To operate the SPT hammer, set the mode switch to drilling (Control J, Figure 3.3). Ensure that the SPT hammer hoses are connected to the top two outputs on the rig PTO (see 3.5.1). The PTO lever on the main console (Control H, Figure 3.2) controls the SPT Auto Hammer motor. The height of the SPT Hammer can be adjusted using the tooling winch control (Control M, Figure 3.3).

3.7 CABLE PERCUSSION OPERATION

To operate in Cable Percussion mode, set the mode switch to drilling (Control J, Figure 3.3). With the brake off (Control A, Figure 3.3), the Clutch Control on the main console (Control B, Figure 3.3) is used to control the percussive action; pull to lift and push to drop. Cable speed can be adjusted using the hoisting reel speed control (Control C, Figure 3.3).

SECTION 4

RIG MAINTENANCE AND SERVICE

SECTION 4 – RIG MAINTENANCE AND SERVICE

It is important that the carrying vehicle, deck engine, compressor and other proprietary items, such as mud and foam pumps are maintained per the supplier's instructions provided. Operating instructions for such equipment should be carefully studied before attempting to use the units.

Please refer to the tables at the back of this section for details of recommended lubricants, hydraulic oils and maintenance check intervals.

4.1 ENGINE FUEL

Diesel, refer to engine operating maintenance manual, Appendix A.

4.2 ENGINE OIL

Use SAE 15W-40 mineral oil. Maintenance should be limited to ensuring that the correct level of engine oil is maintained.

4.3 ENGINE COOLANT

Use 50% coolant and 50% clean fresh water. The engine coolant should be ATSM D4985 compliant. Maintenance should be limited to ensuring that the correct level of coolant is maintained.

4.4 COMPRESSOR OIL

Use SAE 10W-30 mineral oil. Refer to compressor operating maintenance manual, Appendix B.

4.5 BRAKE FLUID

Use DOT 4 brake fluid. Maintenance should be limited to ensuring that the correct level of brake fluid is maintained.

4.6 TOOLING WINCH

Use HLP ISO VG 46 oil. Refer to tooling winch operating manual, Appendix C.

4.7 BATTERY

The battery is housed on the trailer module between the main member and outer panel. Maintenance should be limited to ensuring that the correct level of electrolyte is maintained.

4.8 GREASING POINTS

A multipurpose lithium-based grease is recommended. The Mast Pivot, Mast Outer Legs, Crown Sheave Pin and Tow Hitch Overrun require weekly greasing. If fitted, the SPT Hammer Carriage Fabrication will also require weekly greasing. Grease should be applied using a grease gun.

4.9 HYDRAULIC SYSTEM

The importance of ensuring the maximum attention to cleanliness cannot be over-emphasised when dealing with any servicing of the hydraulic system, from re-filling or topping-up, to the fitting of protective ends to pipes or pipe joint ends.

4.9.1 HYDRAULIC HEADER TANK

A Biodegradable Oil: Holbein NWG 46 should be used. When filling or topping up the hydraulic system, oil can be added via the breather/filler cap located on top of the headache post mounted header tank (Figure. 4.1, Item 15).

This tank assembly includes a combined level and temperature gauge (Figure 4.1, Item 11). It is preferable to keep the system well topped up with the level being maintained within the sight glass. However, it should be remembered that the maximum level will be indicated when all rams are withdrawn, i.e. mast down, stabilising rams retracted etc.

The tank also contains a breather plug fitted with an air filter (Figure. 4.1, Item 6) which requires no maintenance.

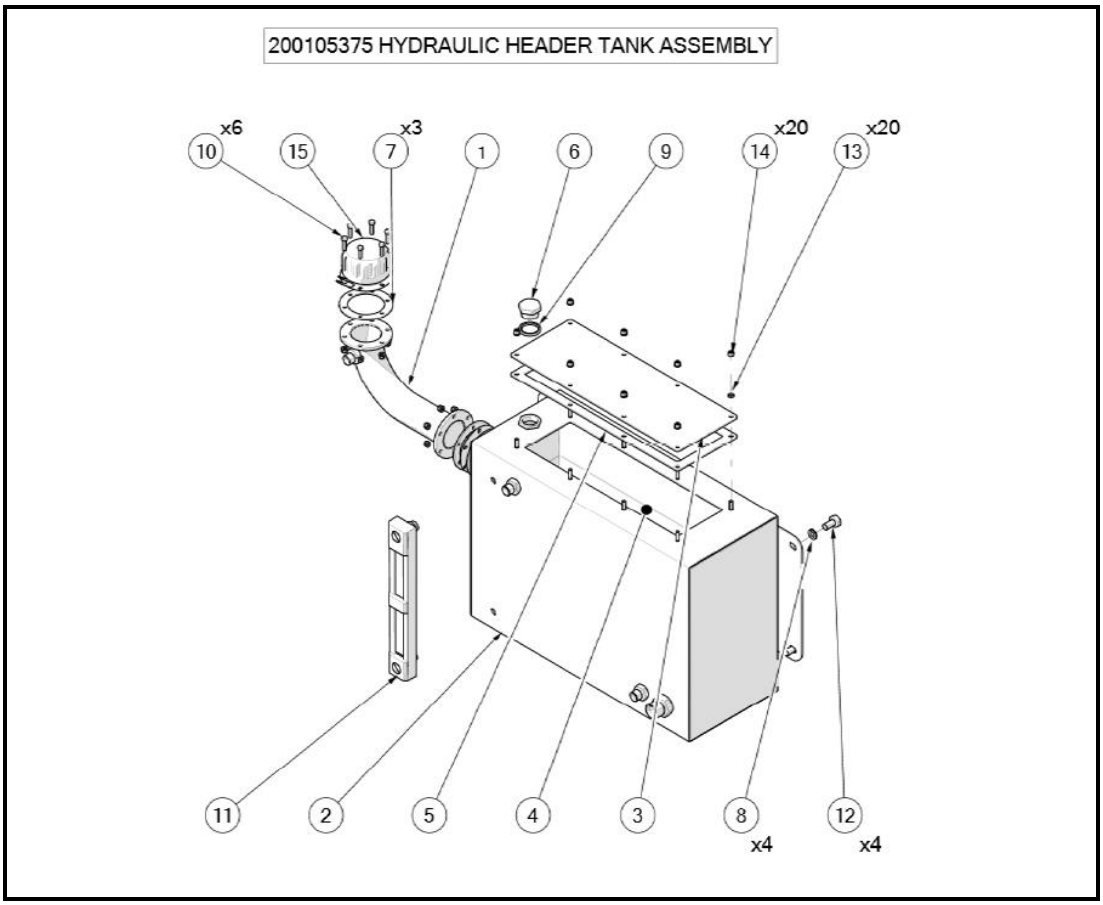


FIGURE 4.1 – HYDRAULIC HEADER TANK

4.9.2 HYDRAULIC CHASSIS TANK

The oil passes from the header tank to the main chassis tank by internal galleries. This tank contains no serviceable items, however, should the tank need emptying this can be carried out using the magnetic plug fitted to the base of the tank.

The hydraulic oil return filter is mounted on the Hydraulic Chassis Tank (Figure 4.2, Item 9). A pressure gauge is mounted on top of the filter; a pressure above 1.5 bar will indicate the filter becoming blocked and bypassed. The hydraulic oil filter should be replaced at the intervals indicated on the Maintenance Checks Table.

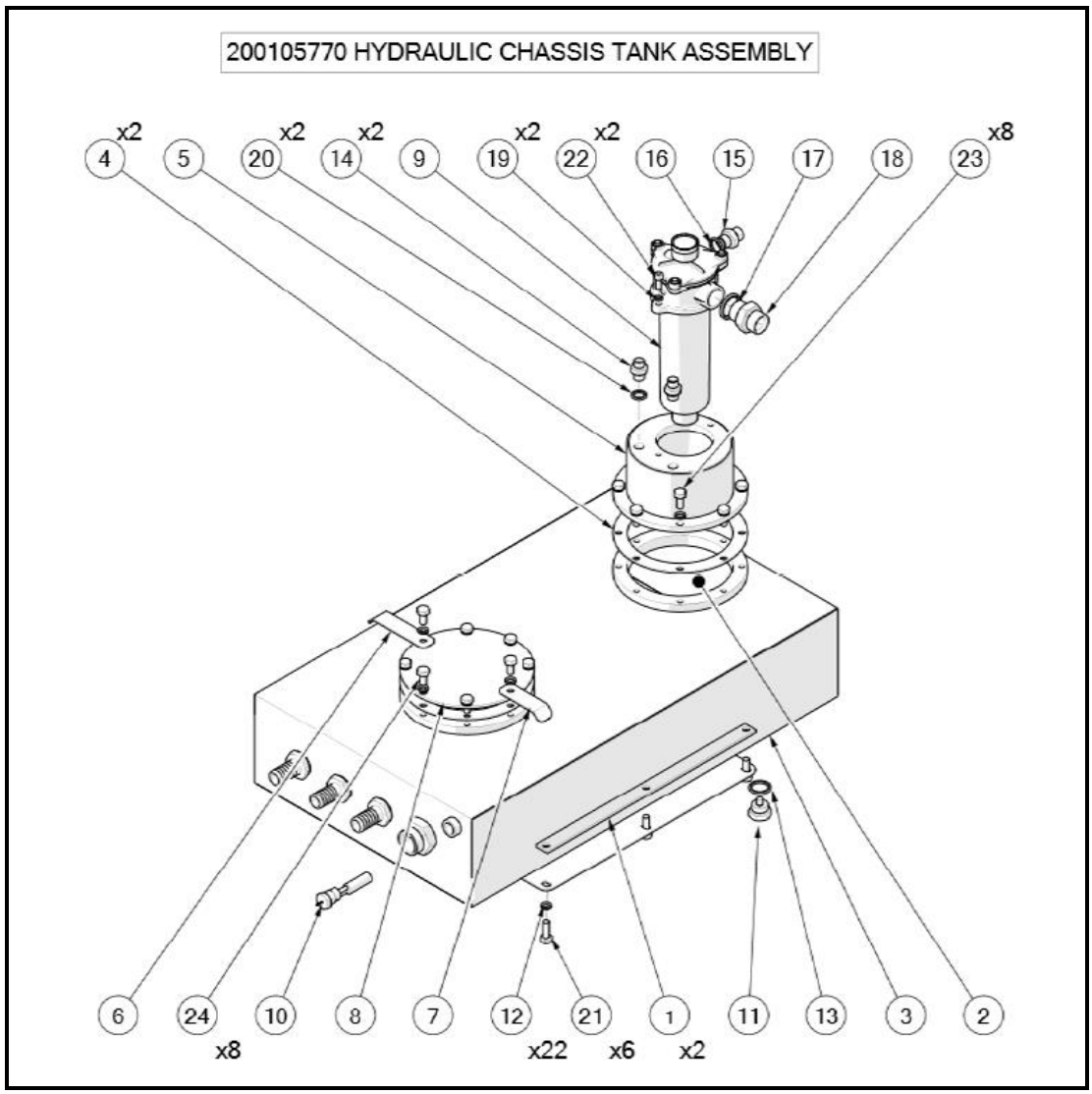


FIGURE 4.2 – HYDRAULIC CHASSIS TANK

4.9.3 HYDRAULIC TANK BREATHER ASSEMBLY

The Hydraulic Tanks Assembly contains a Breather Assembly with an Air Breather Filter which requires no maintenance.

4.10 CONTROL CIRCUITS

After leaving the pressure filters, the hydraulic oil enters the control circuits, the routine maintenance of which is limited to ensuring that the joints are kept tight and hoses in good condition.

4.11 TO FIT NEW LEVELLING JACK CYLINDER

The hydraulic rams may in due course require attention such as the replacement of the gland seal. In order to carry out maintenance, the rear rams have to be removed from the jack housing. This can be done by allowing the ram, together with the bottom section of the jack to drop downwards into a hole or other suitable cavity immediately below the jack. To carry this out, put the jack foot onto the ground then disconnect the two pipes which pass through the side of the jack casing. There is a top cross pin which locates the top of the ram and which passes through the jack casing; this can be removed and by lifting the bottom section of the jack the ram can now be worked upward sufficiently to enable a cross bar to be put through the ram head.

The bottom section of the jack unit can now be disconnected by driving out the cross pin which locates the ram rod at the bottom of the jack extension tube. The ram can now be lifted from the housing for servicing (see illustration of stabilising rams in spare parts listing).

4.12 PRESTART/SHUTDOWN CHECKS

The Daily Maintenance Checks as included in Table 4.3 should be performed before starting the rig and after shutting down the rig. In addition:

- Ensure that all control levers return freely to their rest positions after use.

- Ensure that the Holding Brake Safety Lock (Control A, Figure 3.3) operates correctly in its rest position.

- With the rig running and Holding Brake applied engage the Clutch to ensure that the brake holds, and the drum does not rotate.

- Check the operation of the Fine Feed Brake lever to ensure that it does not bottom out or reach the end of its travel before the brake holds.

- Check the overrun device is operational by lifting tooling on the main hoist cable to activate the device.

Should any of the rig equipment be damaged it should be rectified or replaced before use.

ITEM	LUBRICANT	APPLICATION METHOD
HYDRAULIC MINERAL OILS (Ambients - 10° to + 39°C) For other oils or higher ambient temperatures refer to Service Division, or your local oil company representative	**SHELL**: TRIAD 68 **MOBIL**: DTE 24 **BP**: ENERGOL HLP 32 **ESSO**: NUTO HP32 TELLUS 46 ISO 46 Compliant	Oil Filled
MAST PULLEYS, RAM BEARINGS, MAST PIVOT BUSH AND ALL GREASE POINTS, MATERIAL SLIDES ETC.	General Purpose Lithium-Based Grease e.g: Shell Alvenia R3 Mobil Grease MP BP Energrease LS2	Grease Gun or Brush as appropriate
WIRE ROPES	**SHELL**: CARDIUM COMPOUND **MOBIL**: MOBILTAC A **BP**: ENERGOL WRP **CASTROL**: RUSTILO DWX 32	
RIG ENGINE OIL	15W 40 Refer to Manufacturers Handbook for equivalents	Oil Filled
RIG ENGINE COOLANT	**EXOL:** Antifreeze ASTM D4985 Compliant	Oil Filled
AIR COMPRESSOR OIL	10W 30	Oil Filled
BRAKE FLUID	DOT 4	Oil Filled
TOOLING WINCH	HLP ISO VG 46	Oil Filled

TABLE 4.1 – RECOMMENDED LUBRICANTS

MAXIMUM CONTINUOUS OPERATING TEMPERATURE	BP	CASTROL	ESSO	LORCO	SHELL	TEXACO
46°C (115°F)	HLP 32 SHF 32 THB 32	HYPSIN VG 32	NUTO H32	D322	TELLUS 46	RANDO HD32
56°C (133°F)	HLP 46 SHF 46 THB 46	HYPSIN VG 46	NUTO H46	D346	TELLUS 46	RANDO HD46
62°C (143°F)	HLP 68 SHF 68 THB 68	HYPSIN VG 68	NUTO 68	D368	TELLUS 60	RANDO ID68
74°C (165°)	HLP 100 SHF 100 THB 100	HYPSIN VG 100	NUTO H100	D3100	TELLUS 100	RANDO HD100
80°C (176°F)	HLP 100 SHF 100 THB 150 HL 150	HYPSIN AWS150	NUTO H150	-	TELLUS 150	RANDO HD150

TABLE 4.2 – HYDRAULIC OIL CHART

SERVICE INTERVAL	NO	MAINTENANCE CHECKS	CHECK	GREASE	CHANGE
DAILY	1	Engine Oil Level	X		
	2	Radiator Coolant Level	X		
	3	Engine Air Cleaner Service Indicator	X		
	4	Drain Water from Primary Fuel Filter	X		
	5	Engine Systems	X		
	6	Fuel Level	X		
	7	Compressor Oil Level	X		
	8	Hydraulic Oil Level	X		
	9	All Controls	X		
	10	Winch Overrun Device	X		
	11	Visible Leaks	X		
	12	Rig Welding and Bolting	X		
	13	Emergency Stop	X		
	14	Wire Ropes and Lifting Equipment	X		
	15	Mast Sheaves	X		
	16	Hoses	X		
	17	Drain Condensate from Compressor and Receiver Tanks	X		
FOR TRAILER MOUNTED DUKE ONLY	18	Tire Pressure and Tread Depth	X		
	19	Wheel Nut Indicators	X		
	20	Lights, Reflectors and Number Plate	X		
	21	Mudguards	X		
	22	Tow Hitch and Breakaway Cable	X		
	23	Nose Weight	X		
	24	Handbrake Function	X		
	25	Jockey Wheel and Clamp	X		
	26	Wheel Bearing Play	X		
WEEKLY PLUS 1-25	27	Hoisting Drum Brake and Clutch	X	X	
	28	Battery Electrolyte Level	X		
	29	Mast Pivot and Crown Sheave Pin		X	
	30	Tow Hitch Overrun Brake Device		X	
	31	Mast Outer Legs		X	
	32	SPT Carriage Fabrication		X	
QUARTERLY PLUS 1-31	33	Hydraulic Oil and Hydraulic Filters			X

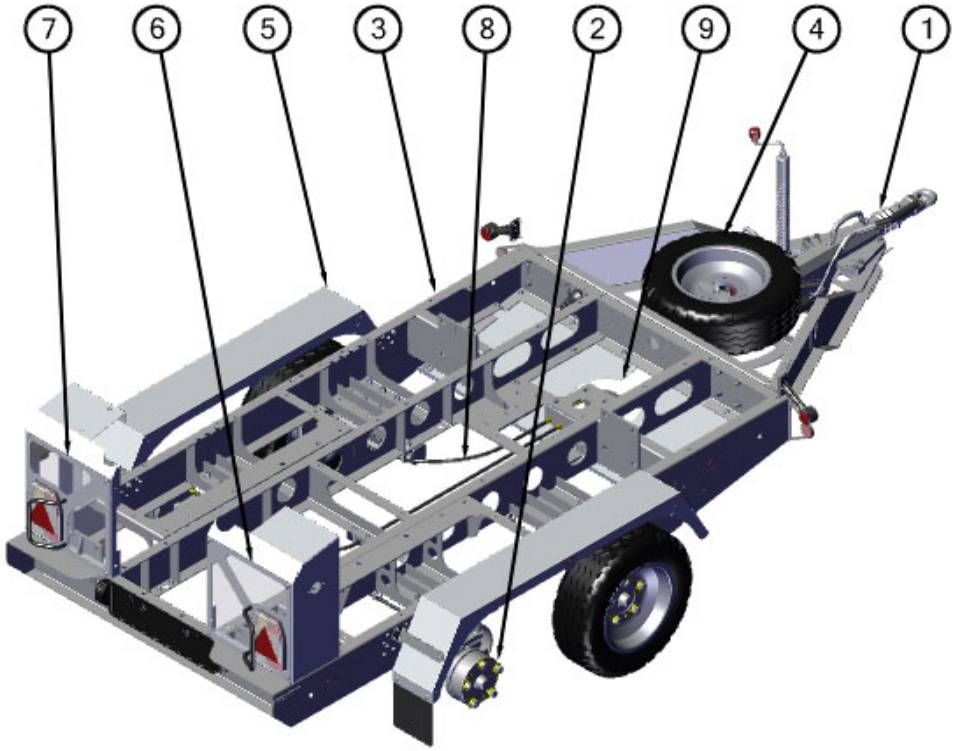
TABLE 4.3 – MAINTENANCE CHECKS

Refer to Manufacturers Handbooks in Appendices for additional information.

SECTION 5

SPARE PARTS ILLUSTRATIONS AND LISTINGS

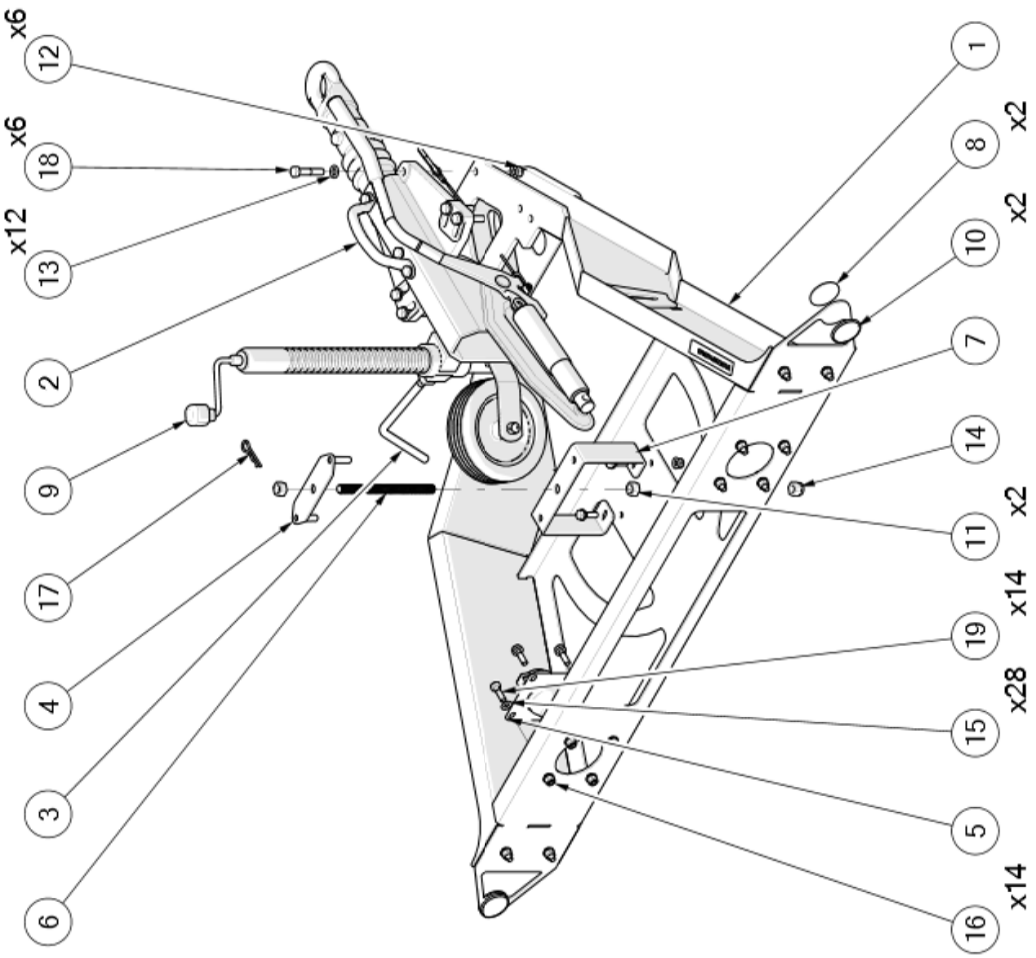
200105418 TRAILER MODULE



200105418 TRAILER MODULE

BOM ID	Number	Description	Qty
1	200105417	DRAW BAR ASSEMBLY	1
2	200105453	TANDEM BRAKED SUSPENSION UNIT ASSY	1
3	200105146	CHASSIS FABRICATION	1
4	200105420	WHEEL MODULE	1
5	200105320	MUD GUARD ASSEMBLY	1
6	200100922	OFFSIDE REAR TRAILER CANOPY & LIGHT ASSEMBLY	1
7	200100923	NEARSIDE REAR TRAILER CANOPY & LIGHT ASSEMBLY	1
8	200105610	BRAKE ASSEMBLY	1
9	200105573	BELLY PLATE ASSEMBLY	1

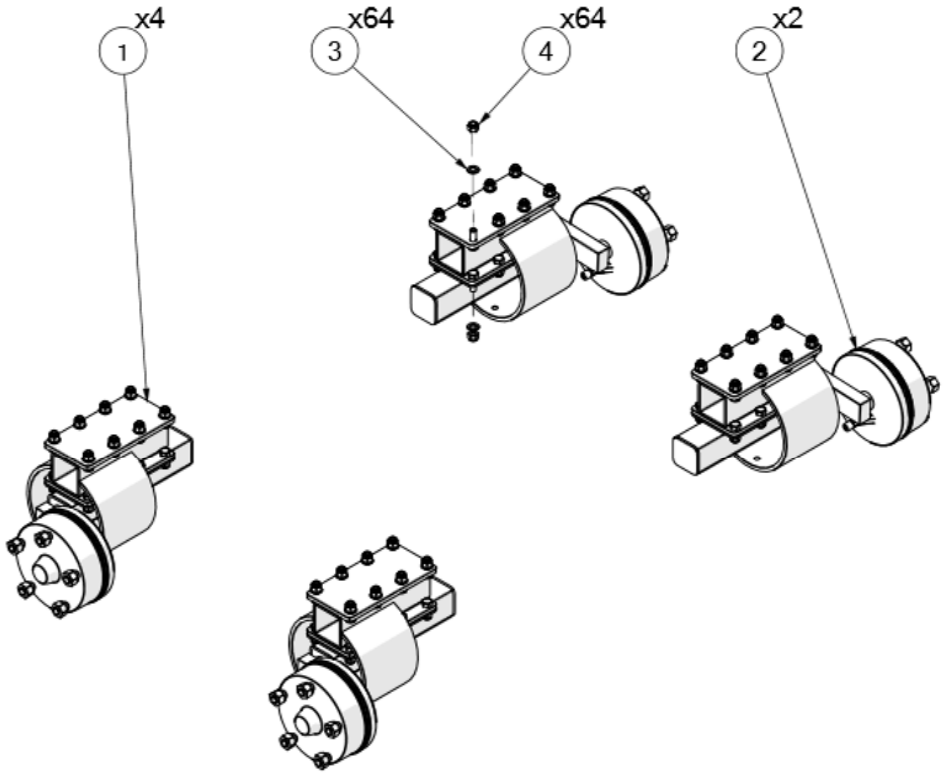
200105417 DRAW BAR ASSEMBLY



200105417 DRAW BAR ASSEMBLY

BOM ID	Number	Description	Qty
1	200100887	TOW HITCH FABRICATION	1
2	200101130	KNOTT AVONRIDE 3500KG TOW HITCH (50MM BALL)	1
3	200105324	EXTENDED HANDLE FOR KNOTT OVERIDE COUPLINGS	1
4	200105327	LOCKING PLATE FABRICATION	1
5	200105517	13 PIN TRAILER PLUG ASSEMBLY	1
6	200105614	SPARE WHEEL LOCKING STUD	1
7	200105713	SPARE WHEEL BRACKET	1
8	910100217	WHITE REFLECTOR	2
9	910100219	RIBBED JOCKEY WHEEL (48MM)	1
10	910100220	RED REFLECTOR	2
11	ST00650X511	M16 ORDINARY NUT	2
12	ST00787X510	M12 NYLOC NUT	6
13	ST00788X881	M12 PLAIN WASHER	12
14	ST00934X510	M16 NYLOC NUT	1
15	ST01048X881	M10 PLAIN WASHER	28
16	ST01109X510	M10 NYLOC NUT	14
17	ST01259X163	GRIP CLIP SPAREX S12 (4mm)	1
18	ST04143X133	M12 HEX HEAD BOLT HT x 60 LONG	6
19	ST04534X133	M10 HEX HEAD BOLT x 35 LONG	14

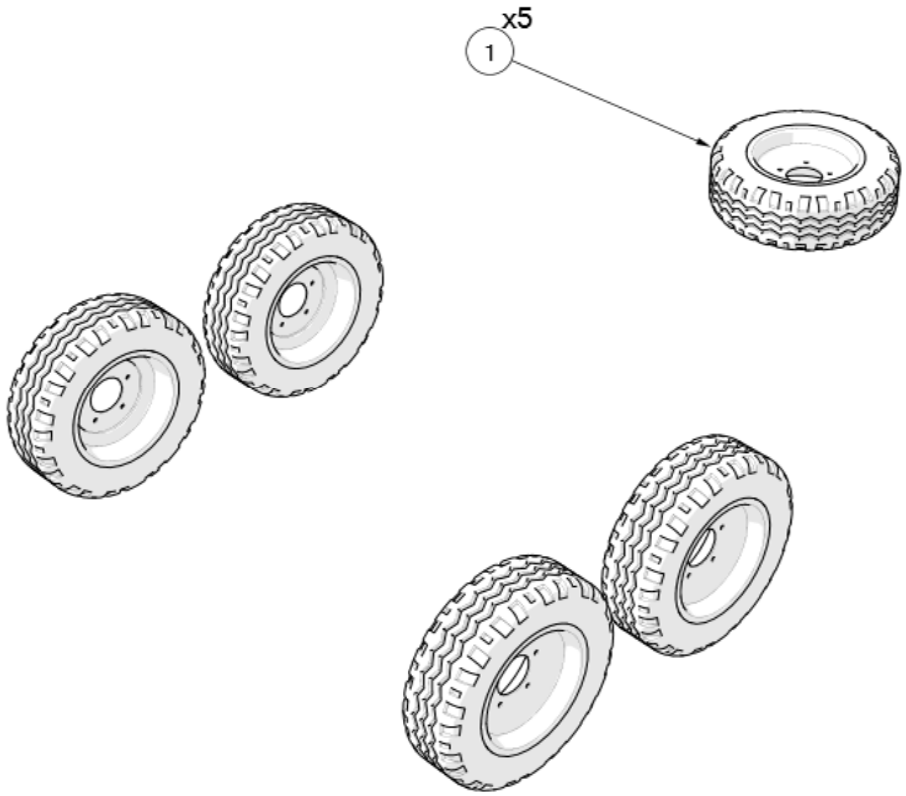
200105453 TANDEM BRAKED SUSPENSION UNIT ASSEMBLY



200105453 TANDEM BRAKED SUSPENSION UNIT ASSEMBLY

BOM ID	Number	Description	Qty
1	200105662	FLEXITOR SPACER [100MM]	4
2	910100216	PEAK 1800KG BRAKED SUSPENSION UNIT (PAIR)	2
3	ST00788X881	M12 PLAIN WASHER	64
4	ST06828X523	M12 NYLOC NUT	64

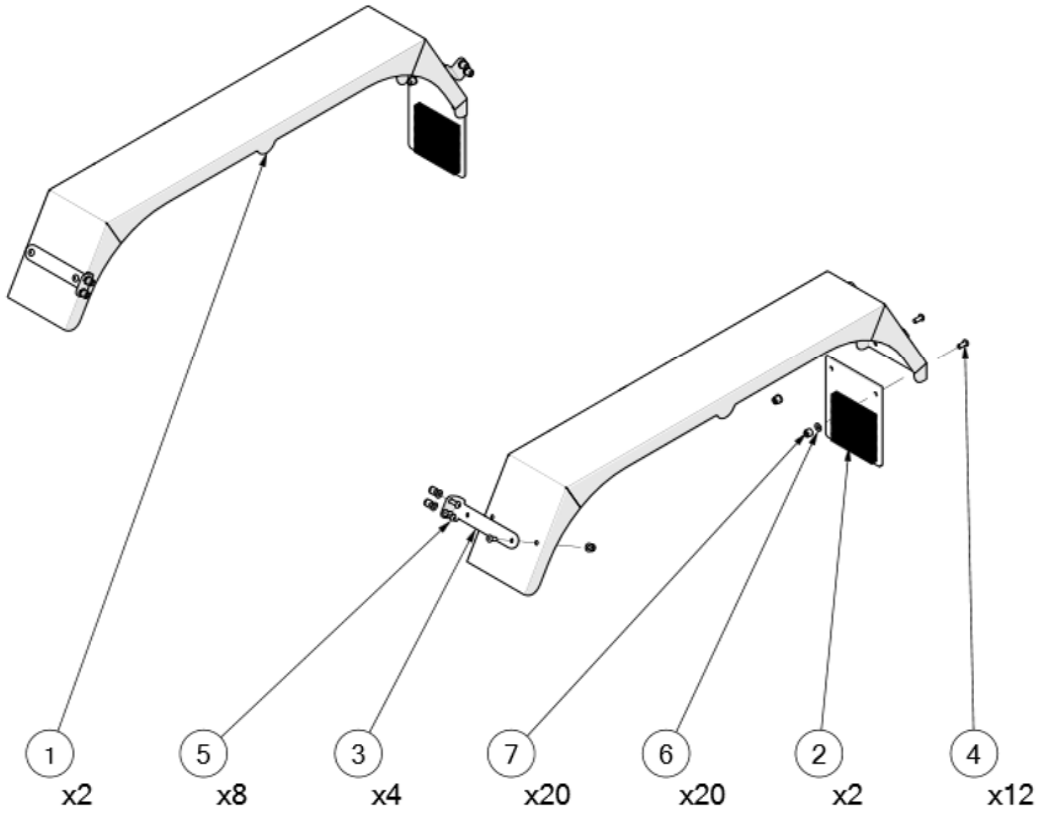
200105420 WHEEL MODULE



200105420 WHEEL MODULE

BOM ID	Number	Description	Qty
1	200101137	185/70 R13, 5 ON 6.5" WHEEL COMPLETE	5

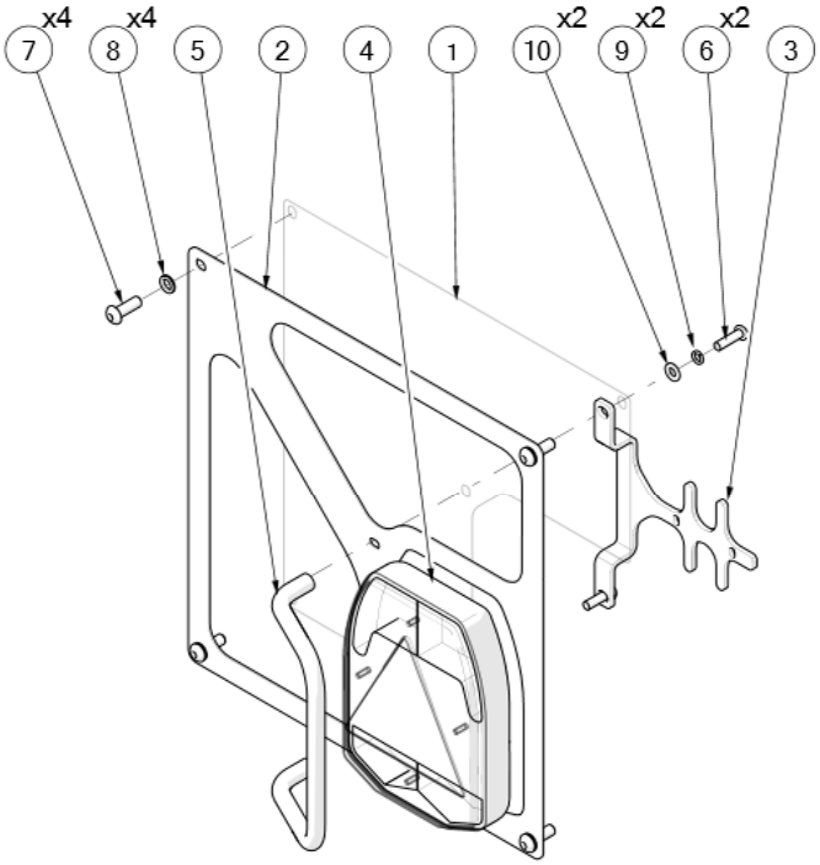
200105320 MUD GUARD ASSEMBLY



200105320 MUD GUARD ASSEMBLY

BOM ID	Number	Description	Qty
1	200105317	MUDGUARD	2
2	200105318	MUD FLAP	2
3	200105319	MOUNTING BRACKET (MUD GUARD)	4
4	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	12
5	C100G00912	M10 S.S. HEX SOC BUTTON HEAD SCREW X 30 LG	8
6	ST01048X881	M10 PLAIN WASHER	20
7	ST01109X510	M10 NYLOC NUT	20

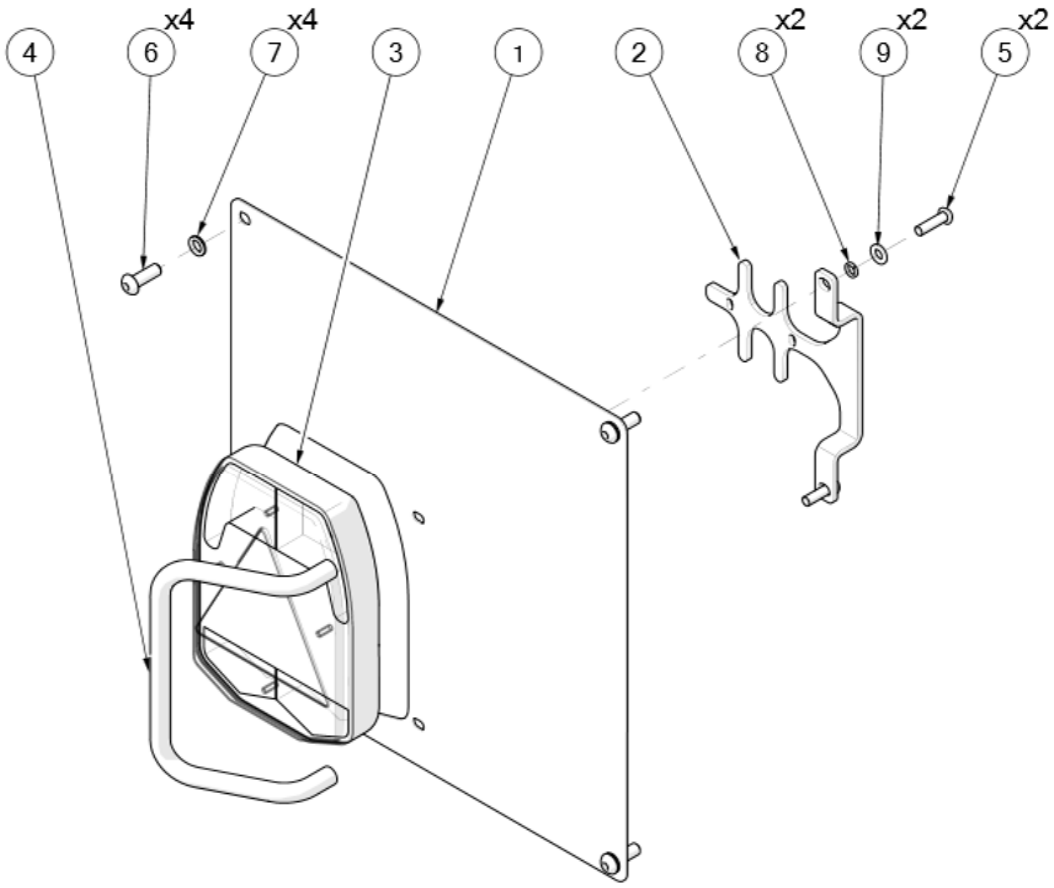
200100922 OFFSIDE REAR TRAILER CANOPY & LIGHT ASSEMBLY



200100922 OFFSIDE REAR TRAILER CANOPY & LIGHT ASSEMBLY

BOM ID	Number	Description	Qty
1	200101495	REAR MESH [TRAILER]	1
2	200101496	REAR LIGHT PANEL	1
3	200101499	REAR LIGHT MOUNT	1
4	800100185	RADEX 6900 6-F CLUSTER RH ASSEMBLY	1
5	900100143	BOW HANDLE BLACK	1
6	C10000944	M8 SOCKET BUTTON HEAD CAPSCREW x 30 LG.	2
7	C100G00912	M10 S.S. HEX SOC BUTTON HEAD SCREW X 30 LG	4
8	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	4
9	ST01146X885	M8 SPRING WASHER	2
10	ST10249X883	M8 PLAIN BRIGHT WASHER	2

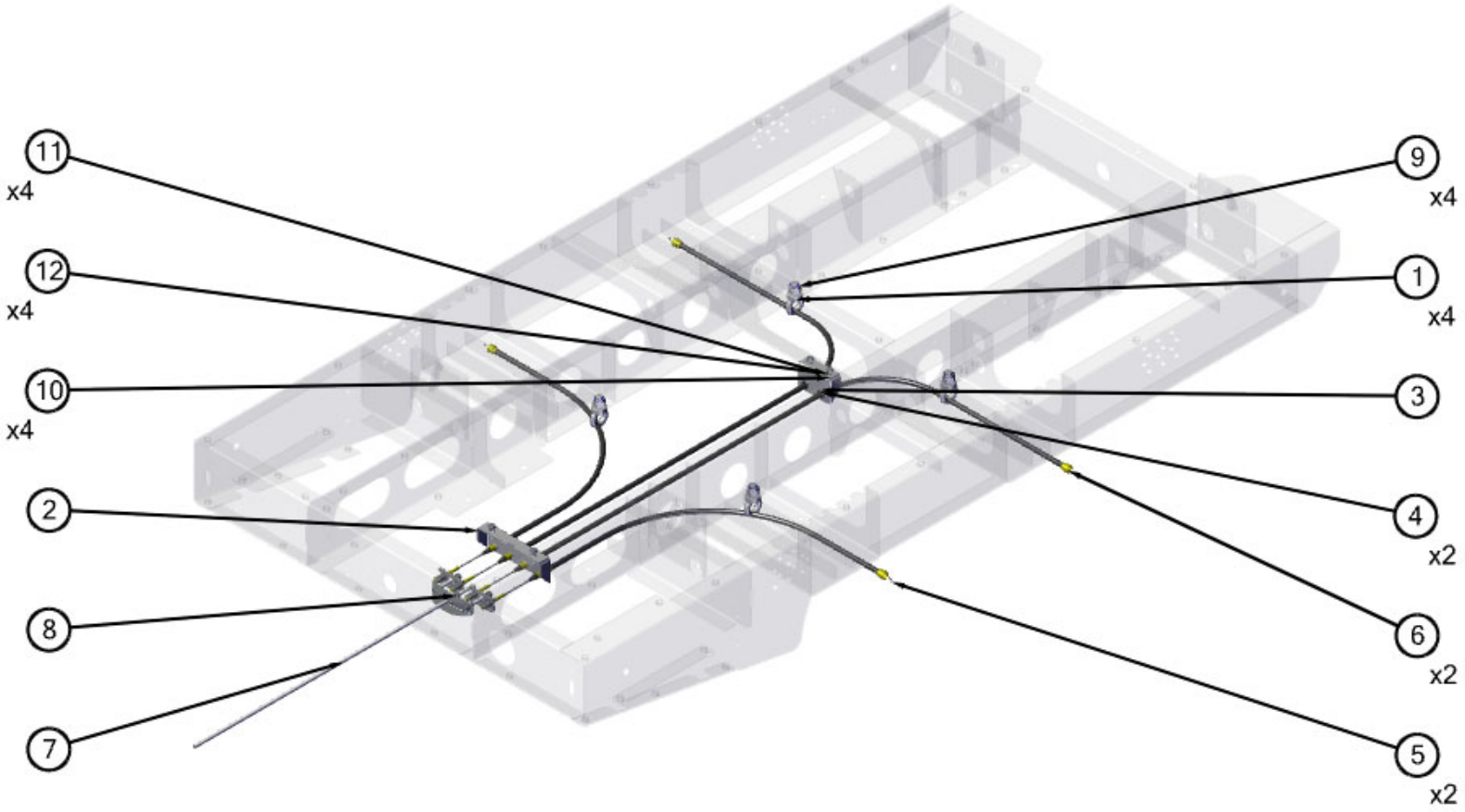
200100923 NEARSIDE REAR TRAILER CANOPY & LIGHT ASSEMBLY



200100923 NEARSIDE REAR TRAILER CANOPY & LIGHT ASSEMBLY

BOM ID	Number	Description	Qty
1	200101496	REAR LIGHT PANEL	1
2	200101499	REAR LIGHT MOUNT	1
3	800100186	RADEX 6900 6-F CLUSTER LH ASSEMBLY	1
4	900100143	BOW HANDLE BLACK	1
5	C10000944	M8 SOCKET BUTTON HEAD CAPSCREW x 30 LG.	2
6	C100G00912	M10 S.S. HEX SOC BUTTON HEAD SCREW X 30 LG	4
7	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	4
8	ST01146X885	M8 SPRING WASHER SINGLE COIL	2
9	ST10249X883	M8 PLAIN BRIGHT WASHER	2

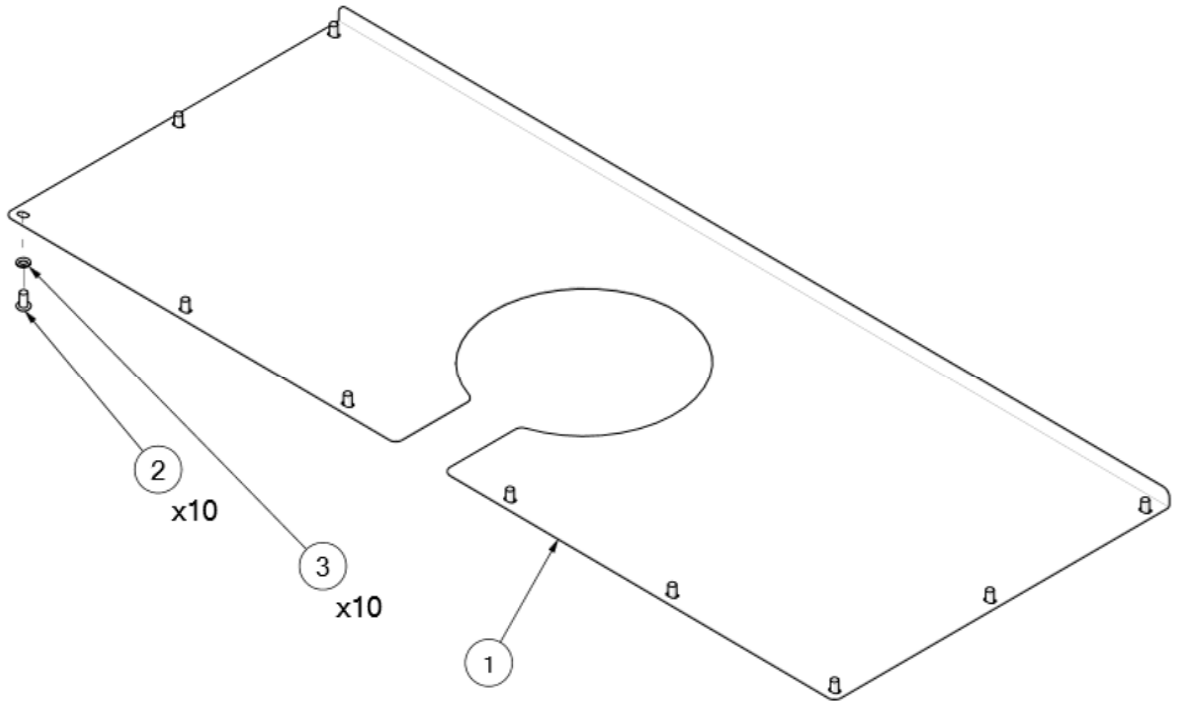
200105610 BRAKE ASSEMBLY



200105610 BRAKE ASSEMBLY

BOM ID	Number	Description	Qty
1	200101169	M20 EYEBOLT (EBM20)	4
2	200101330	CABLE RETAINER - 4	1
3	200101331	CABLE RETAINER - 2	1
4	200101335	GROMMET RUBBER 16.1 I/D x 20 O/D	2
5	200101336	DETACHABLE BRAKE CABLE 1230LG	2
6	910100215	DETACHABLE BRAKE CABLE 2030LG	2
7	200105611	HANDBRAKE ADJUSTER ROD	1
8	C103C0019	TANDEM AXLE COMPENSATOR KIT	1
9	ST00713X510	M20 NYLOC - SELF LOCKING NUT	4
10	ST01109X510	M10 NYLOC NUT	4
11	ST04534X133	M10 HEX HEAD BOLT x 35 LONG	4
12	ST05104X883	M10 PLAIN BRIGHT WASHER	4

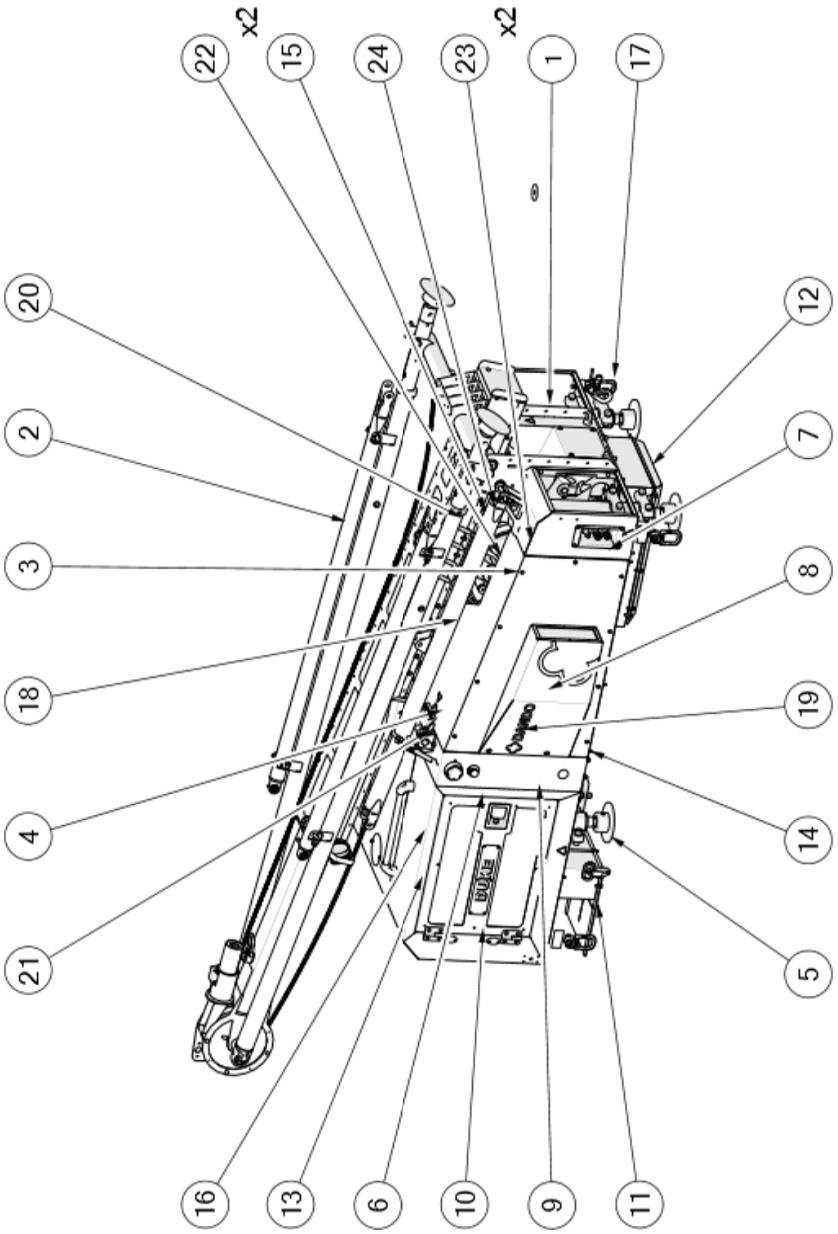
200105573 BELLY PLATE ASSEMBLY [TRAILER]



200105573 BELLY PLATE ASSEMBLY [TRAILER]

BOM ID	Number	Description	Qty
1	200105572	BELLY PLATE [TRAILER]	1
2	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	10
3	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	10

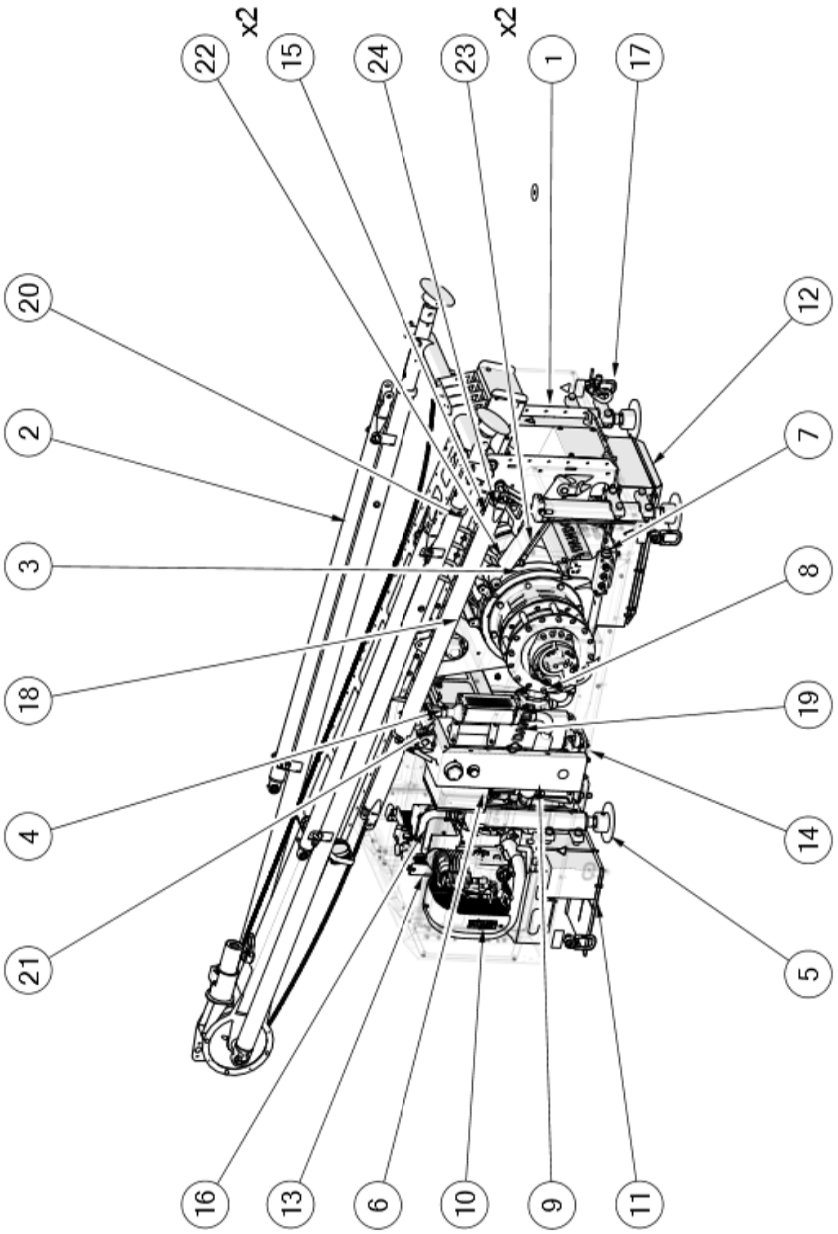
200105153 CORE RIG



200105153 CORE RIG

BOM ID	Number	Description	Qty
1	200105282	A-FRAME ASSEMBLY	1
2	200105965	MAST ASSEMBLY	1
3	200105110	HOISTING REEL ASSEMBLY	1
4	200105191	HEADACHE POST ASSEMBLY	1
5	200105171	LEVELLING JACK ASSEMBLY	1
6	200105357	FUEL TANK ASSEMBLY (44L)	1
7	200105783	HYDRAULIC TANKS ASSEMBLY	1
8	200800305	HYDRAULIC PUMP ASSEMBLY [DANDO DUKE CLOSED LOOP, 2 x TANDEM GEAR PUMPS]	1
9	200105501	ELECTRICAL CONTROL ASSEMBLY [DUKE]	1
10	200800237	COMPRESSOR MODULE	1
11	200105510	BATTERY ASSEMBLY	1
12	200105355	GUARD ASSEMBLY (HYD OIL TANK)	1
13	200105152	ENGINE ASSEMBLY	1
14	200105457	CANOPY ASSEMBLY	1
15	200105483	CONTROL CONSOLE ASSEMBLY	1
16	200105605	OIL COOLER ASSEMBLY	1
17	200105452	LIFTING EYE ASSEMBLY	1
18	200105460	AIR HOSE REEL ASSEMBLY	1
19	200105471	LIVERY AND DECALS (DANDO DUKE)	1
20	200105741	DANDO DUKE SAFETY DECALS	1
21	200108353	STOWAGE ASSEMBLY - SPREADER BAR	1
22	200101161	70 BORE x 40 ROD x 400 STROKE DOUBLE ACTING CYLINDER	2
23	200102250	0.375 IN BSP BANJO SWAGED HOSE [FRONT JACK]	2
24	200105950	SPREADER BAR FABRICATION	1

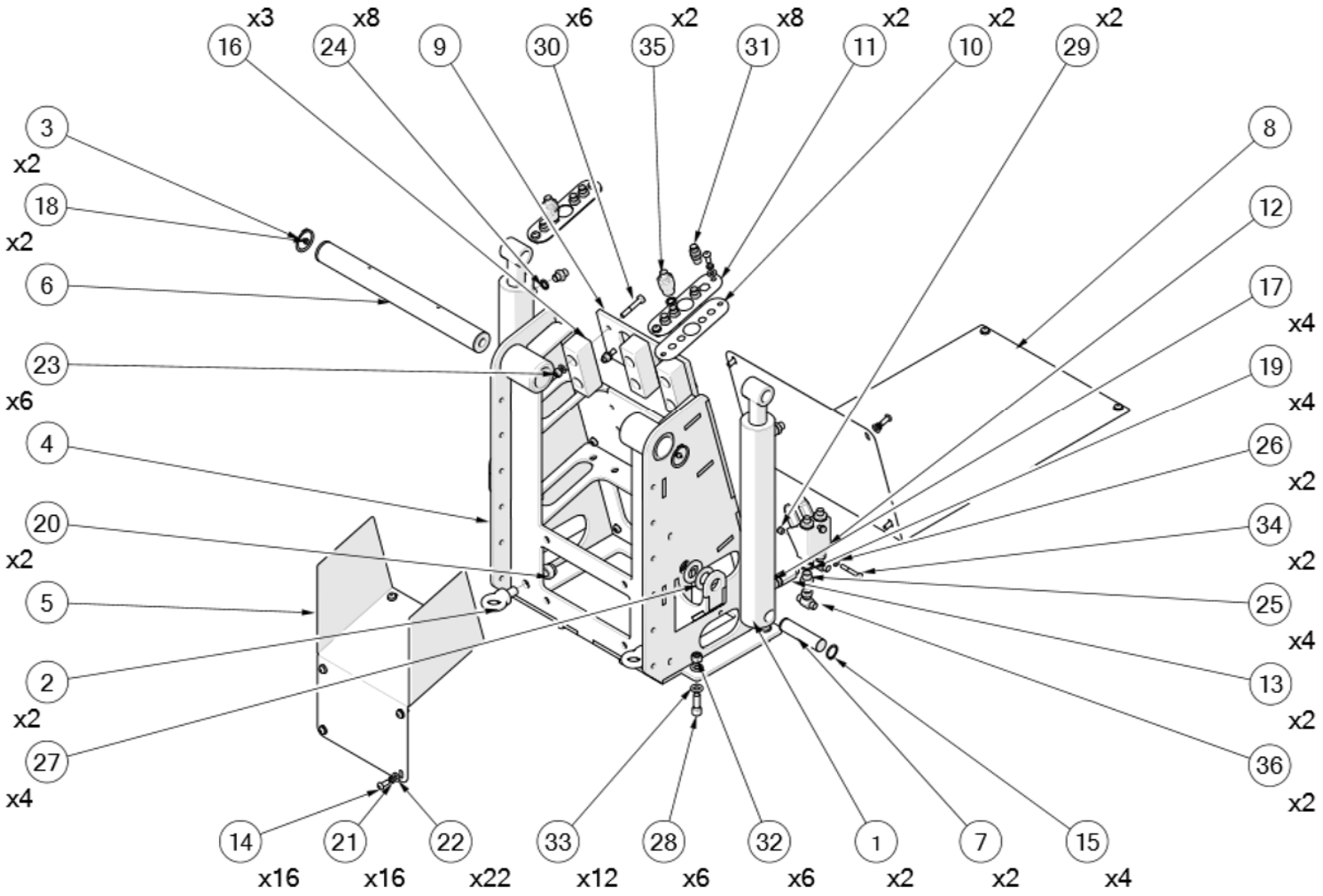
200105153 CORE RIG



200105153 CORE RIG

BOM ID	Number	Description	Qty
1	200105282	A-FRAME ASSEMBLY	1
2	200105965	MAST ASSEMBLY	1
3	200105110	HOISTING REEL ASSEMBLY	1
4	200105191	HEADACHE POST ASSEMBLY	1
5	200105171	LEVELLING JACK ASSEMBLY	1
6	200105357	FUEL TANK ASSEMBLY (44L)	1
7	200105783	HYDRAULIC TANKS ASSEMBLY	1
8	200800305	HYDRAULIC PUMP ASSEMBLY [DANDO DUKE CLOSED LOOP, 2 x TANDEM GEAR PUMPS]	1
9	200105501	ELECTRICAL CONTROL ASSEMBLY [DUKE]	1
10	200800237	COMPRESSOR MODULE	1
11	200105510	BATTERY ASSEMBLY	1
12	200105355	GUARD ASSEMBLY (HYD OIL TANK)	1
13	200105152	ENGINE ASSEMBLY	1
14	200105457	CANOPY ASSEMBLY	1
15	200105483	CONTROL CONSOLE ASSEMBLY	1
16	200105605	OIL COOLER ASSEMBLY	1
17	200105452	LIFTING EYE ASSEMBLY	1
18	200105460	AIR HOSE REEL ASSEMBLY	1
19	200105471	LIVERY AND DECALS (DANDO DUKE)	1
20	200105741	DANDO DUKE SAFETY DECALS	1
21	200108353	STOWAGE ASSEMBLY - SPREADER BAR	1
22	200101161	70 BORE x 40 ROD x 400 STROKE DOUBLE ACTING CYLINDER	2
23	200102250	0.375 IN BSP BANJO SWAGED HOSE [FRONT JACK]	2
24	200105950	SPREADER BAR FABRICATION	1

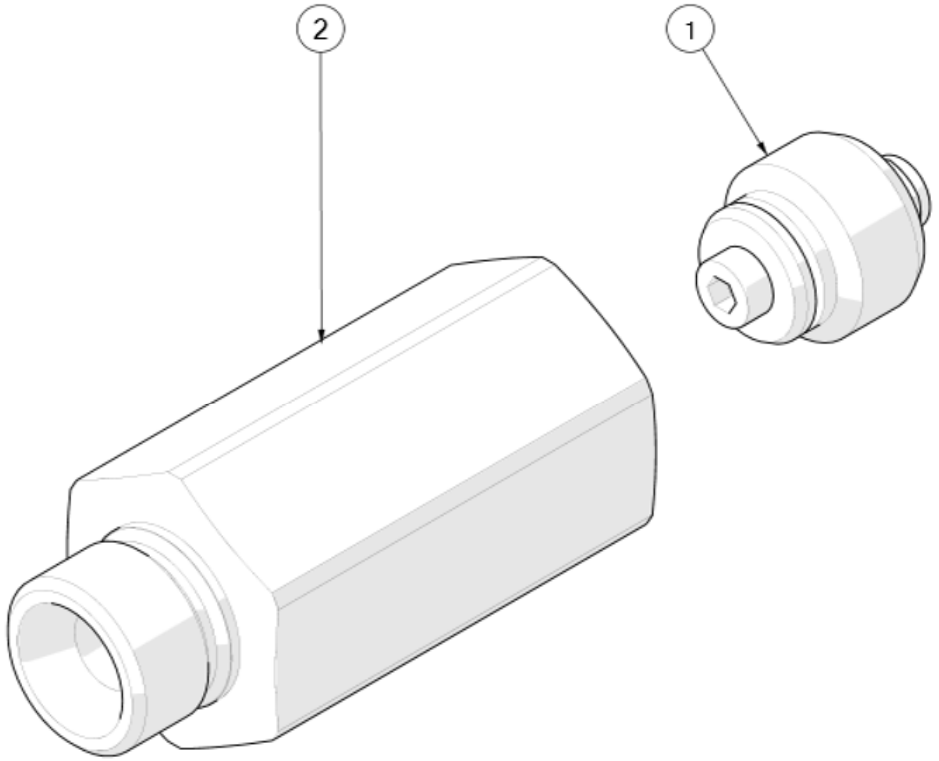
200105282 A-FRAME ASSEMBLY



200105282 A-FRAME ASSEMBLY

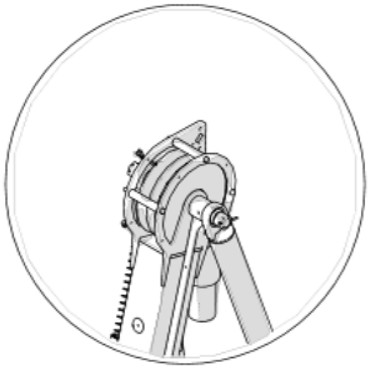
BOM ID	Number	Description	Qty
1	200101161	70 BORE x 40 ROD x 400 STROKE DOUBLE ACTING CYLINDER	2
2	200101169	M20 EYEBOLT (EBM20)	2
3	200101188	EXTERNAL CIRCLIP 50 DIA	2
4	200105224	A-FRAME FABRICATION	1
5	200105285	A-FRAME COVER (FRONT)	1
6	200105286	MAST PIVOT PIN	1
7	200105442	LOCATION PIN - 30 DIA X 114 BTWN CIRCLIPS	2
8	200105601	A-FRAME COVER (REAR)	1
9	200105606	RUBBER BUFFER SPACER	1
10	200105607	A-FRAME BULK HEAD PLATE	2
11	200105609	A-FRAME BULK HEAD LOCK PLATE	2
12	700100123	COUNTERBALANCE VALVE	1
13	700200256	0.375IN HOSE BURST VALVE ASSY [VUBA380 & VUBA61100088]	2
14	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	16
15	C100G01131	30 DIA STANDARD EXTERNAL CIRCLIP DIN 471	4
16	C100G01629	RUBBER BUFFER 150 x 50 x 50	3
17	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	4
18	ST00180X270	1/8" BSP STR GREASE NIPPLE	2
19	ST00246X328	1/2" BSP BONDED SEAL	4
20	ST00713X510	M20 NYLOC - SELF LOCKING NUT	2
21	ST00777X885	M10 SINGLE COIL SPRING WASHER	16
22	ST01048X881	M10 PLAIN WASHER	22
23	ST01109X510	M10 NYLOC NUT	6
24	ST01156X328	3/8"BSP BONDED SEAL	8
25	ST01158X326	1/2" BSP x 3/8" BSP MALE/MALE STUD ADAPTOR	4
26	ST01176X881	M8 PLAIN WASHER	2
27	ST01322X883	M30 PLAIN WASHER (BRIGHT)	4
28	ST01555X743	M14 SOCKET HEAD CAP SCREW x 40 LONG	6
29	ST04379X510	M8 NYLOC NUT	2
30	ST07656X133	M10 HEX HD BOLT HT x 60 LONG	6
31	ST08827X315	3/8" BSP MALE/MALE [60° CONE] BULKHEAD C/W LOCK NUT	8
32	ST09871X510	M14 NYLOC NUT	6
33	ST10167X883	M14 BRIGHT PLAIN WASHER	12
34	ST11625X133	M8 HEX HEAD BOLT HT x 55 LG.	2
35	ST12407X329	3/8" BSP x 3/8" BSP MALE/FEMALE INLINE SWIVEL ADAPTOR (ISIS - 820400001)	2
36	ST12422X335	0.375IN BSPP M x BSPP M x F SWIVEL BRANCH TEE	2

700200256 0.375IN HOSE BURST VALVE ASSEMBLY [VUBA380 & VUBA61100088]

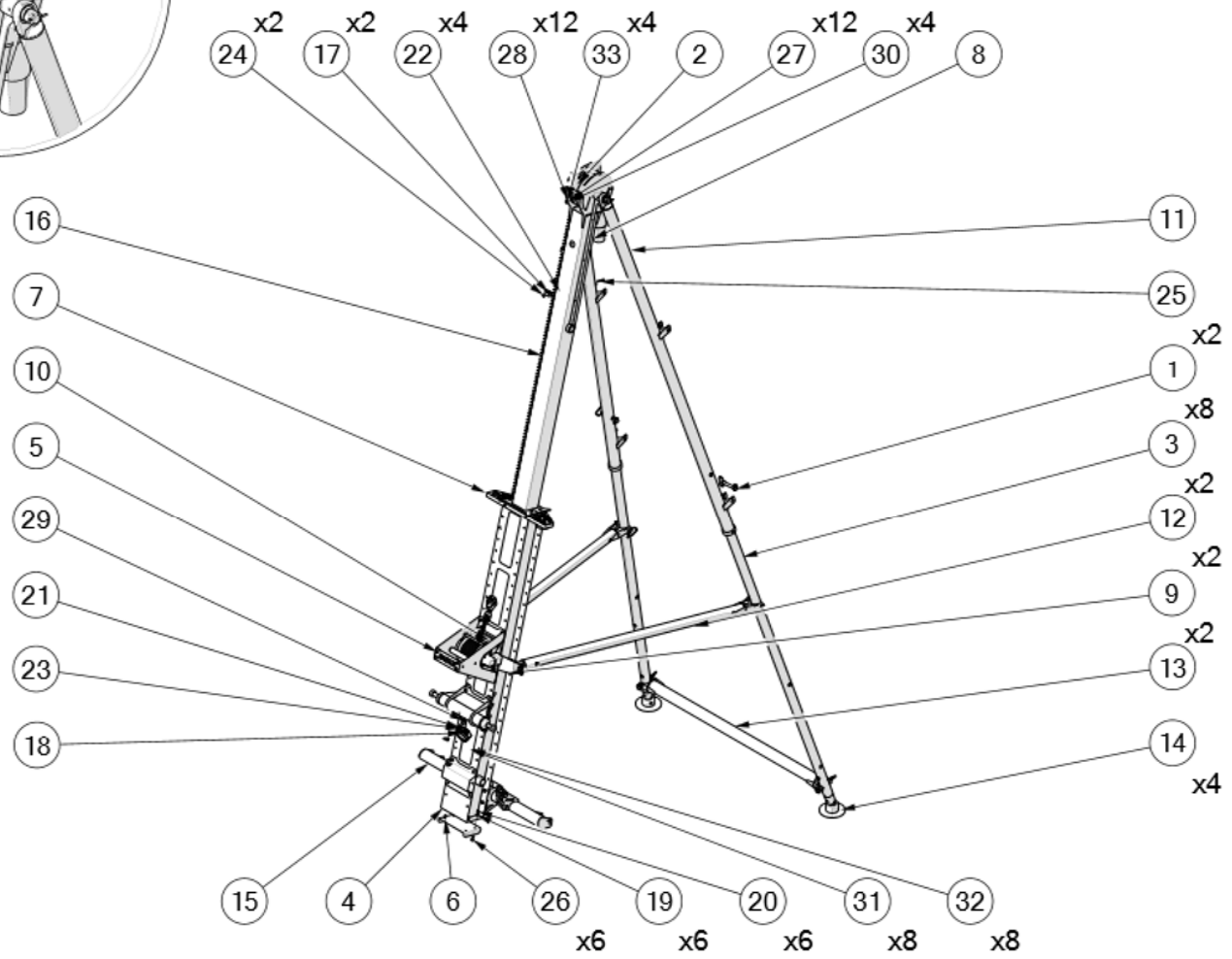


700200256 0.375IN HOSE BURST VALVE ASSEMBLY [VUBA380 & VUBA61100088]

BOM ID	Number	Description	Qty
1	ST11790X850	3/8" BSP HOSE BURST CARTRIDGE (VUBA380)	1
2	ST11791X850	3/8" BSP MALE/FEMALE HOSE BURST HOUSING (VUBA 61100088)	1



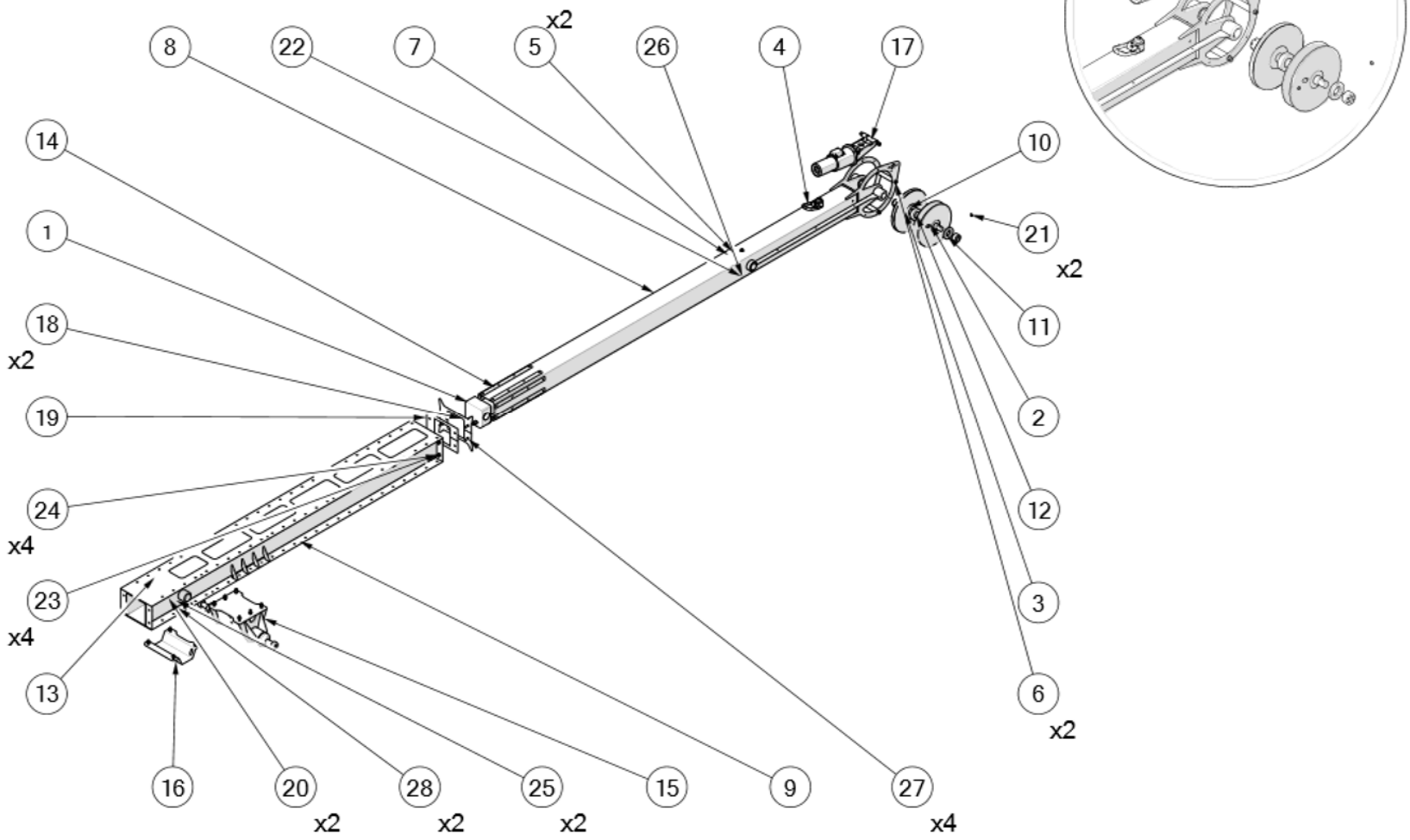
200105965 MAST ASSEMBLY



200105965 MAST ASSEMBLY

BOM ID	Number	Description	Qty
1	200101121	20 DIA HITCH PIN 145 LG, CW LINCH PIN & CHAIN	8
2	200105238	OUTER LEG SUB-ASSY	1
3	200105241	INNER LEG FAB	2
4	200105253	MAST SUB-ASSY	1
5	200105258	WHIP CHECK ASSEMBLY	1
6	200105288	END CAP [BOTTOM]	1
7	200105513	MAIN MAST LIGHTING ASSEMBLY	1
8	200105537	SAFETY 2 BLOCK WEIGHT NEOPRENE RUBBER GUARD	1
9	200105708	CROSS BAR BRACKET	2
10	200105715	0.44 TONNE WINCH ASSY [NP05 - DANDO DUKE]	1
11	200105798	OUTER LEG SUB-ASSY [LEFT]	1
12	200105941	SIDE BAR FABRICATION	2
13	200105950	SPREADER BAR FABRICATION	1
14	200105959	MAST FOOT ASSEMBLY	4
15	200105963	TIE BAR SUPPORT ASSEMBLY	1
16	800100176	2 CORE COILED CABLE 0.75MM YELLOW (1M)	1
17	800100268	CABLE CLEATS (27.8 0 30.4MM)	2
18	C108G0083	WORK LAMP 6 X LED 12 24V [L&S 042 065]	1
19	ST01048X881	M10 PLAIN WASHER	6
20	ST01109X510	M10 NYLOC NUT	6
21	ST01146X885	M8 SPRING WASHER SINGLE COIL	1
22	ST01176X881	M8 PLAIN WASHER	4
23	ST02091X511	M8 THIN NUT	1
24	ST04379X510	M8 NYLOC NUT	2
25	ST05718X133	M8 HEX HEAD BOLT x 65 LONG	2
26	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	6
27	ST09754X883	M5 PLAIN WASHER - BRIGHT	12
28	ST09755X510	M5 NYLOC NUT	12
29	ST09902X478	SHOCK ABSORBER - BUFFER TYPE A 30/20-M8 x 20 NR 57 SHORE A	1
30	ST10131X788	M5 SCREW PAN HEAD RECESSED x 20 LONG	4
31	ST11125X163	13MM BLACK STAINLESS STEEL P CLIP	8
32	ST11135X788	M5 SCREW PAN HEAD RECESSED X 15 LONG	8
33	ST11197X163	6MM P CLIP RUBBER LINED JCS	4

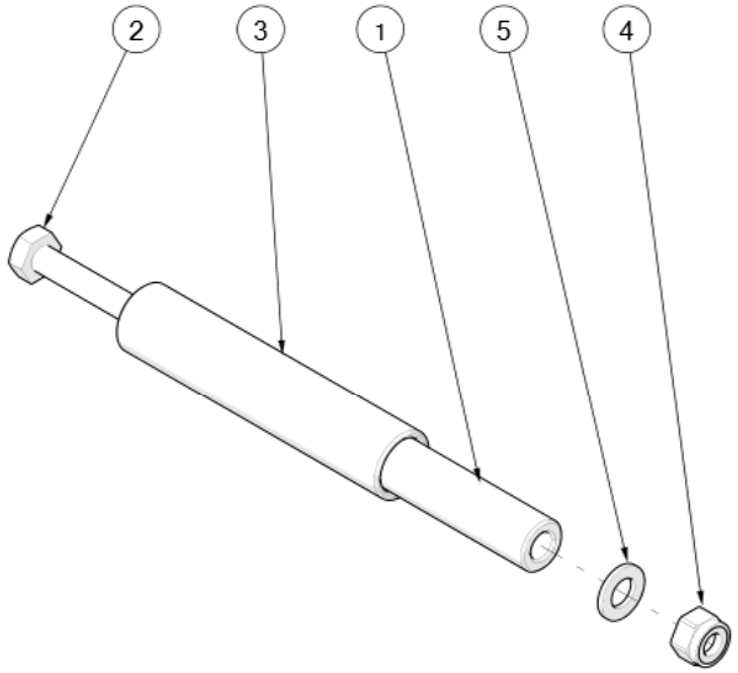
200105253 MAST SUB-ASSEMBLY



200105253 MAST SUB-ASSEMBLY

BOM ID	Number	Description	Qty
1	200101102	TELESCOPIC MAST BOOM CYLINDER (1800 STROKE)	1
2	200101106	CROWN SHEAVE (16MM WIRELINE)	1
3	200101109	CROWN SHAFT	1
4	200101160	3.5T LIFTING EYE (RUD VLBG-PLUS)	1
5	200101188	EXTERNAL CIRCLIP 50 DIA	2
6	200101191	CROWN WIRELINE RETAINER ASSEMBLY	2
7	200101193	LOCATION PIN 50 DIA X 202 BETWEEN CIRCLIPS	1
8	200105197	INNER MAST FABRICATION	1
9	200105213	OUTER MAST FAB	1
10	200105392	OPTIONAL TOOLING SHEAVE [8MM]	1
11	200105393	SPACER	1
12	200105394	SPACER	1
13	200105402	MAST RAM DUMMY PIN	1
14	200105403	INNER MAST WEAR STRIP ASSEMBLY	1
15	200105404	MAST RAISE BRACKET ASSEMBLY	1
16	200105526	MAST HYD GUARD ASSEMBLY	1
17	200105999	OVERRUN DEVICE ASSY	1
18	200800228	MAST END CAP	2
19	200800229	MAST END CAP RUBBER SEAL	1
20	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	2
21	ST00180X270	1/8" BSP STR GREASE NIPPLE	2
22	ST00777X885	M10 SINGLE COIL SPRING WASHER	1
23	ST01048X881	M10 PLAIN WASHER	4
24	ST01109X510	M10 NYLOC NUT	4
25	ST01156X328	3/8"BSP BONDED SEAL [DOWTY]	2
26	ST05368X715	M10 HEX HEAD SET SCREW HT x 40 LG.	1
27	ST10229X647	M10 HEX HEAD BOLT x 35 LG FOR RH11 FLUSHING HEAD (Pt.No: 0510 075)	4
28	ST20108X332	3/8" BSP 90 DEG. FEMALE SWEPT HOSE END	2

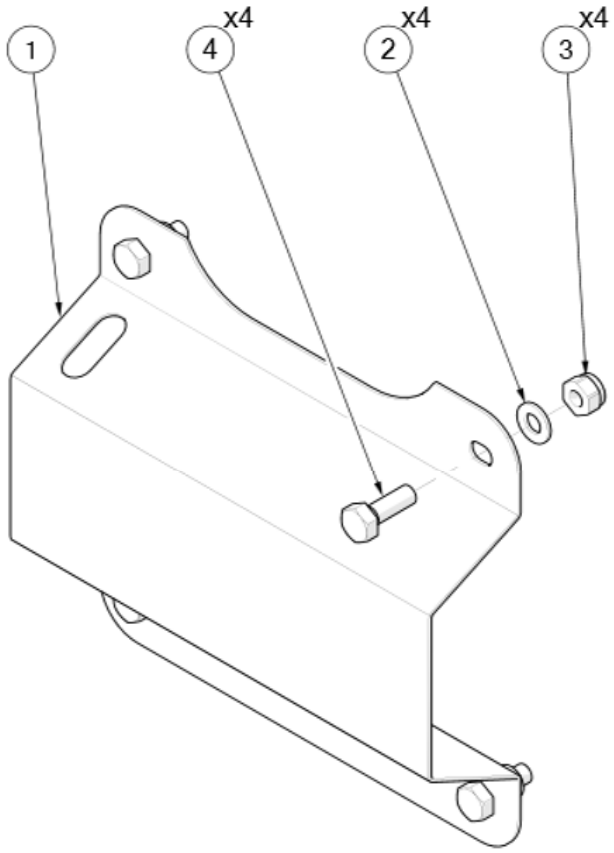
200101191 CROWN WIRELINE RETAINER ASSEMBLY



200101191 CROWN WIRELINE RETAINER ASSEMBLY

BOM ID	Number	Description	Qty
1	200101190	CROWN WIRELINE RETAINER	1
2	200101192	M10 HEX HEAD X 170 LONG	1
3	200105391	ROLLER - MAST CROWN	1
4	ST01109X510	M10 NYLOC NUT	1
5	ST05104X883	M10 PLAIN BRIGHT WASHER	1

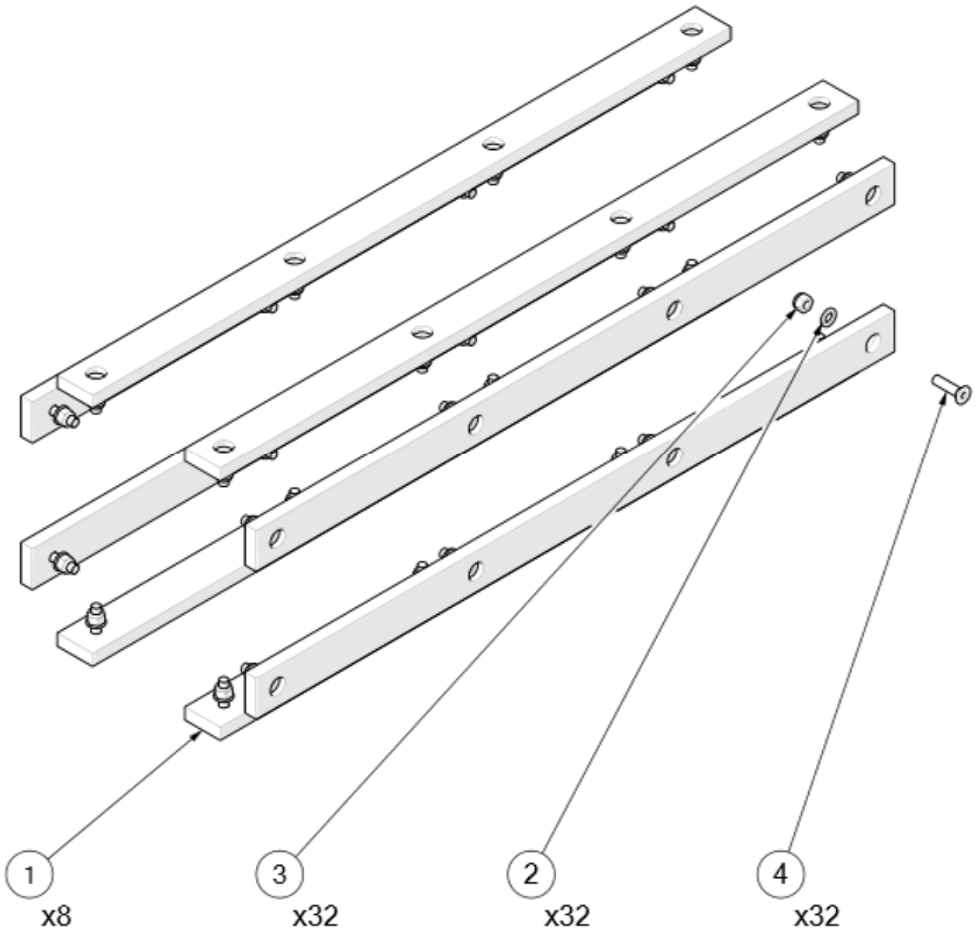
200105526 MAST HYDRAULIC GUARD ASSEMBLY



200105526 MAST HYDRAULIC GUARD ASSEMBLY

BOM ID	Number	Description	Qty
1	200105525	MAST HYD GUARD	1
2	ST01048X881	M10 PLAIN WASHER	4
3	ST01109X510	M10 NYLOC NUT	4
4	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	4

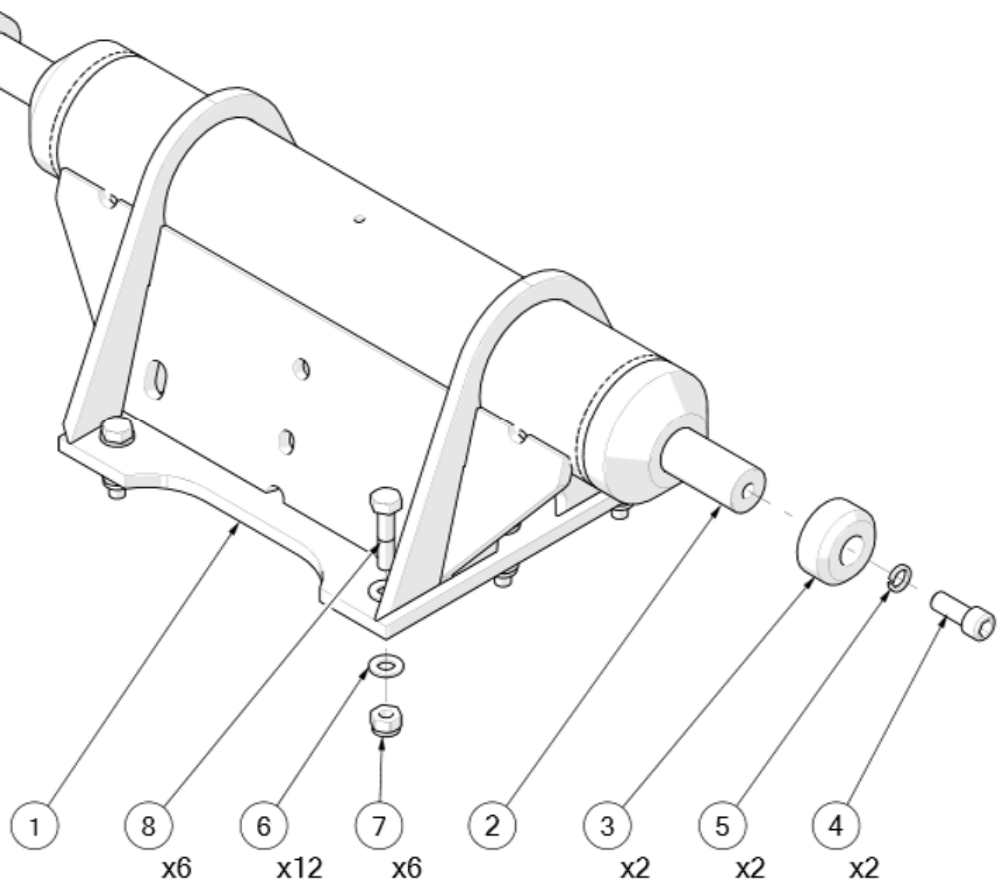
200105403 INNER MAST WEAR STRIP ASSEMBLY



200105403 INNER MAST WEAR STRIP ASSEMBLY

BOM ID	Number	Description	Qty
1	200101101	INNER MAST WEAR STRIP	8
2	ST09754X883	M5 PLAIN WASHER - BRIGHT	32
3	ST09755X510	M5 NYLOC NUT	32
4	ST12435X763	M5 SOCKET HEAD COUNTERSUNK SCREW x 20 LONG	32

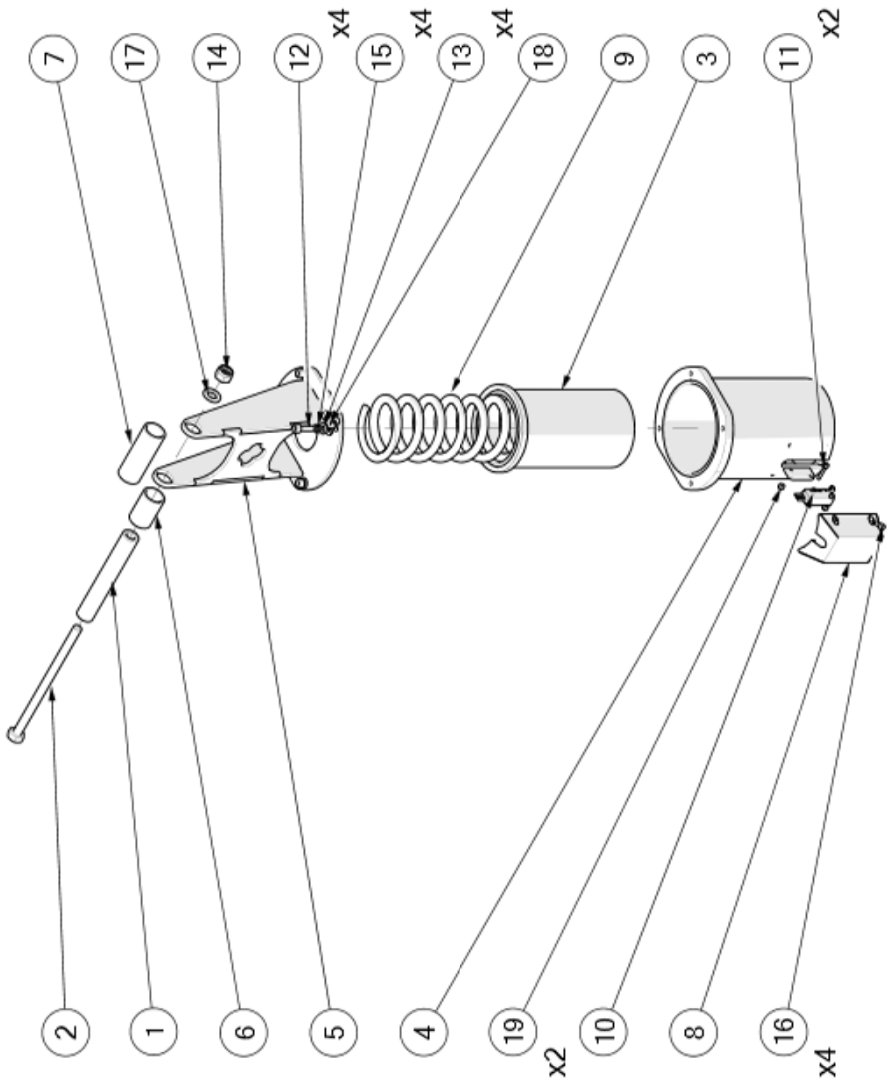
200105404 MAST RAISE BRACKET ASSEMBLY



200105404 MAST RAISE BRACKET ASSEMBLY

BOM ID	Number	Description	Qty
1	200105248	MAST RAISE FAB	1
2	200105405	RAISE RAM PIN	1
3	C002M012130	RAISE RAM PIN END CAP [MT4000 MK3]	2
4	ST00573X743	M12 SOCKET HD CAP SCREWx 30 LG	2
5	ST00648X885	M12 SPRING WASHER - SINGLE COIL	2
6	ST01048X881	M10 PLAIN WASHER	12
7	ST01109X510	M10 NYLOC NUT	6
8	ST10209X133	M10 HEX HEAD BOLT HT x 45 LG.	6

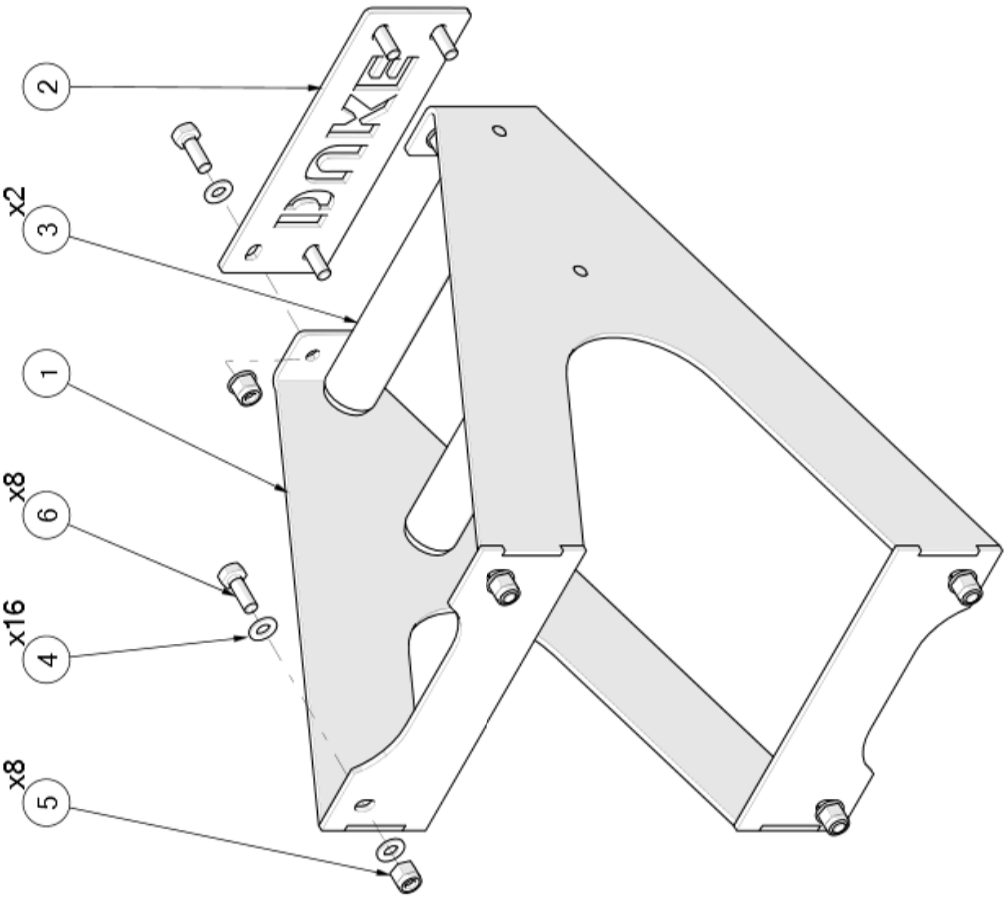
200105999 OVERRUN DEVICE ASSEMBLY



200105999 OVERRUN DEVICE ASSEMBLY

BOM ID	Number	Description	Qty
1	200101190	CROWN WIRELINE RETAINER	1
2	200101192	M10 HEX HEAD X 170 LONG	1
3	200105992	INNER TUBE MACHINED	1
4	200105998	OUTER TUBE MACHINED	1
5	200106320	TOP CAP FAB	1
6	200106321	ROLLER SPACER - MAST CROWN	1
7	200106322	ROLLER SPACER - MAST CROWN	1
8	200106325	MICROSWITCH GUARD	1
9	910102204	2.25IN ID 12IN FREE LENGTH 75LB SPRING	1
10	910102206	SEALED MINIATURE BASIC MICROSWITCH	1
11	910102210	M3 x 20 SOCKET HEAD CAP SCREW	2
12	ST00583X743	M6 SOC HEAD CAP SCREW x 20 lg	4
13	ST01096X881	M6 ORDINARY WASHER	4
14	ST01109X510	M10 NYLOC NUT	1
15	ST01179X885	M6 SPRING WASHER	4
16	ST02629X743	M4 SOCKET HEAD CAP SCREW x 10 LONG	4
17	ST05104X883	M10 PLAIN BRIGHT WASHER	1
18	ST11197X163	6mm "P" CLIP RUBBER LINED JCS	1
19	ST12381X510	M3 NYLOC NUT	2

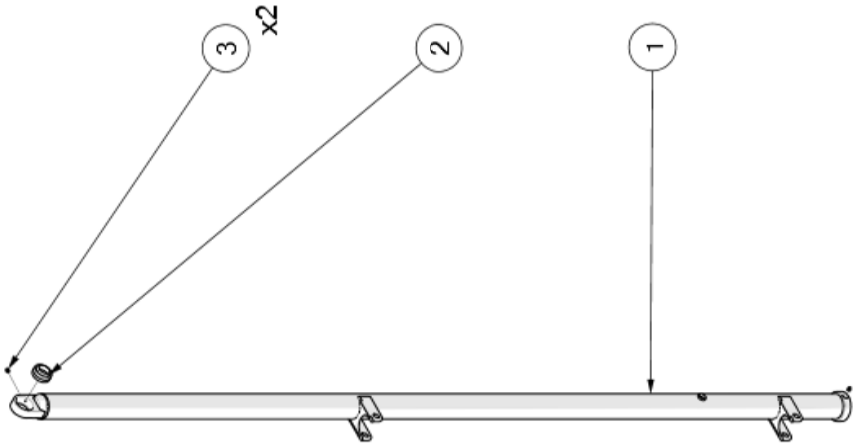
200105258 WHIP CHECK ASSEMBLY



200105258 WHIP CHECK ASSEMBLY

BOM ID	Number	Description	Qty
1	200105257	WHIP CHECK FAB	1
2	200106909	WHIP CHECK SPREAD PLATE	1
3	910102109	SPRING LOADED ROLLER 40 DIA X 250 LG [RD-17W2JF4HAC RL250]	2
4	ST01048X881	M10 PLAIN WASHER	16
5	ST01109X510	M10 NYLOC NUT	8
6	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	8

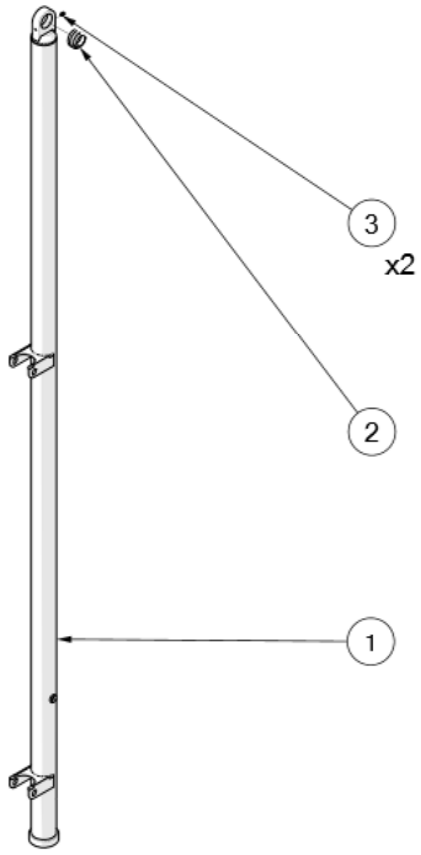
200105238 OUTER LEG SUB-ASSEMBLY [RIGHT]



200105238 OUTER LEG SUB-ASSEMBLY [RIGHT]

BOM ID	Number	Description	Qty
1	200105237	OUTER LEG FAB [RIGHT]	1
2	200101128	40 ID SPHERICAL BEARING (SRL40-2RS)	1
3	ST00180X270	1/8" BSP STR GREASE NIPPLE	2

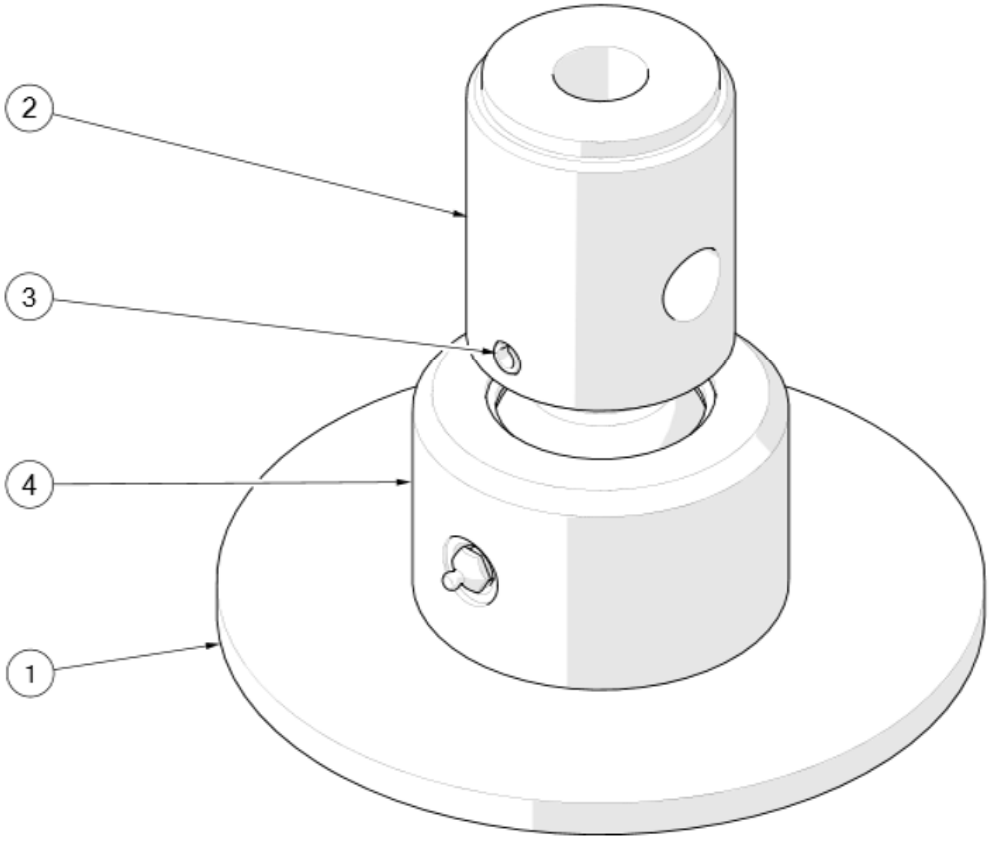
200105798 OUTER LEG SUB-ASSEMBLY [LEFT]



200105798 OUTER LEG SUB-ASSEMBLY [LEFT]

BOM ID	Number	Description	Qty
1	200105797	OUTER LEG FAB [LEFT]	1
2	200101128	40 ID SPHERICAL BEARING (SRL40-2RS)	1
3	ST00180X270	1/8" BSP STR GREASE NIPPLE	2

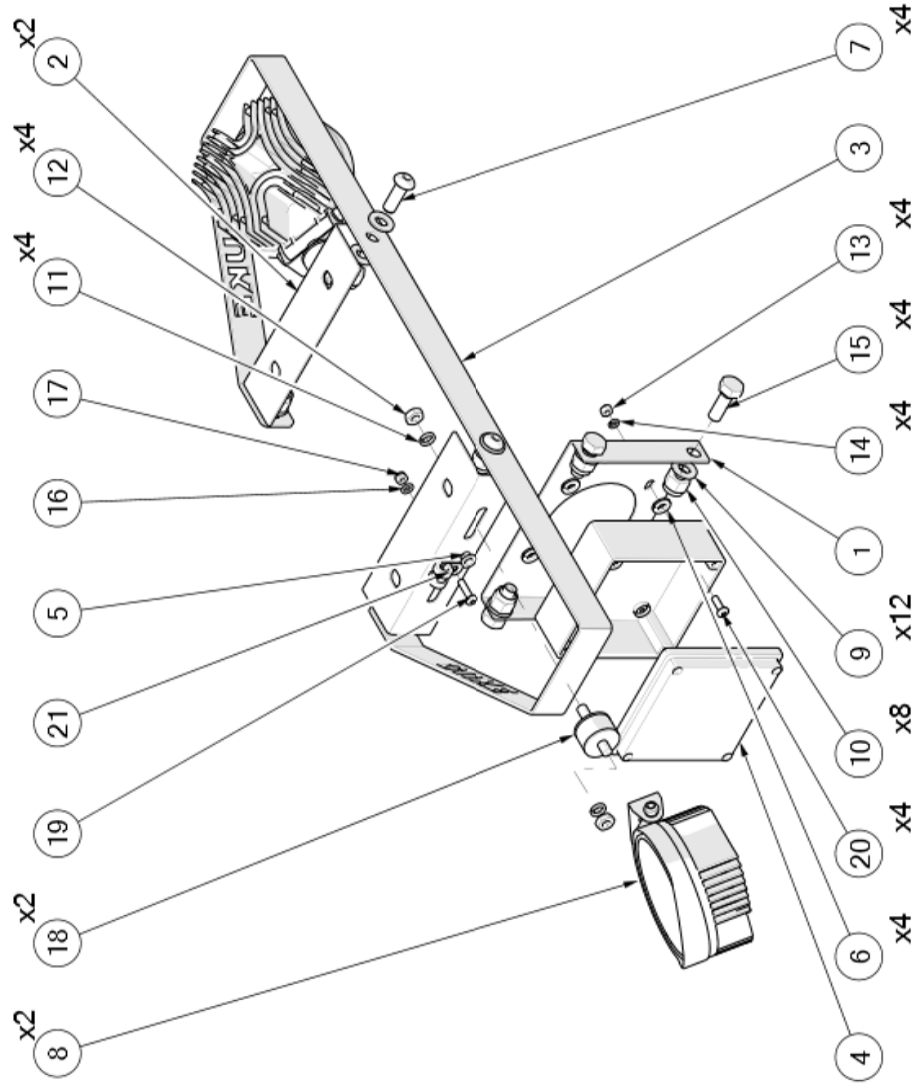
200105959 MAST FOOT ASSEMBLY



200105959 MAST FOOT ASSEMBLY

BOM ID	Number	Description	Qty
1	200101119	FRONT LEG FOOT PLATE	1
2	200105920	LOCATING BOSS (MAST FOOT)	1
3	900100188	10 X 70MM SLOTTED SPRING PIN (STAINLESS STEEL)	1
4	C100C0012	WELDABLE BALL/SOCKET JOINT	1

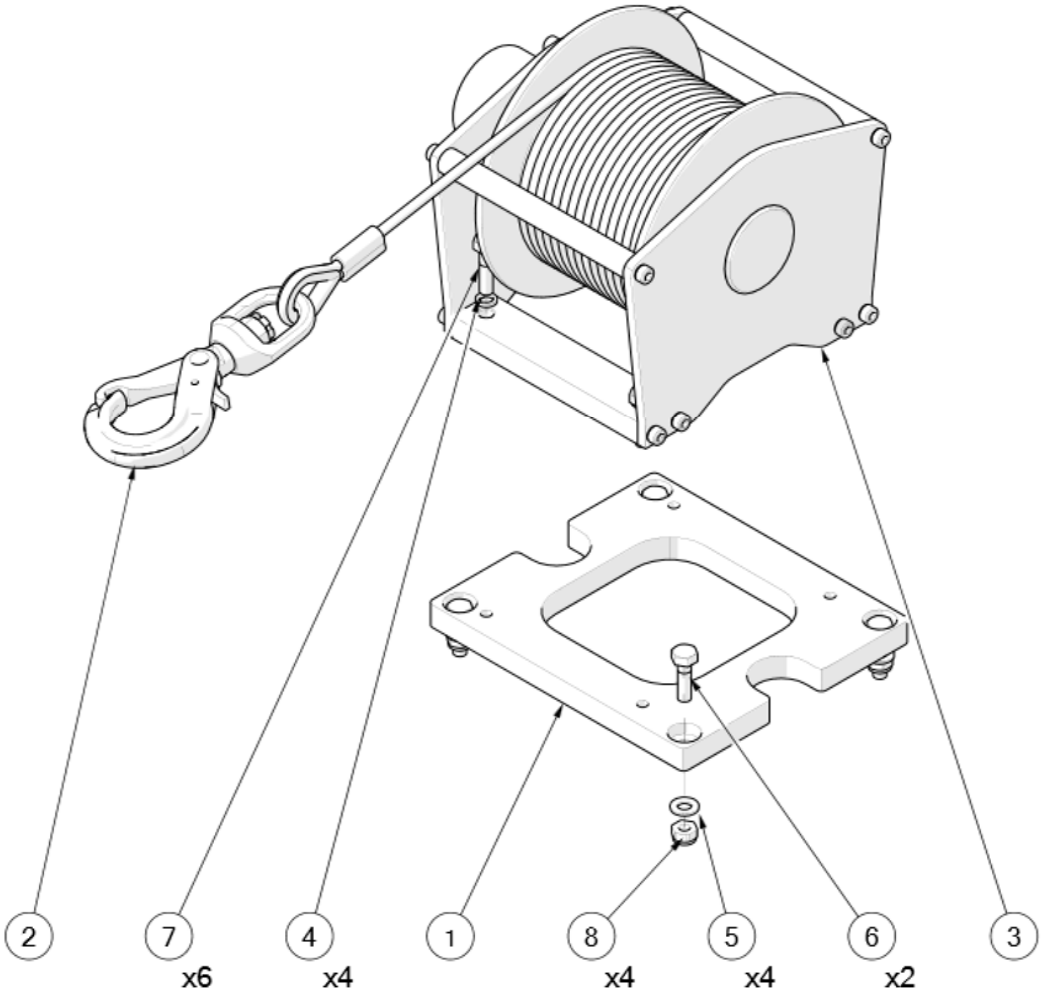
200105513 MAIN MAST LIGHTING ASSEMBLY



200105513 MAIN MAST LIGHTING ASSEMBLY

BOM ID	Number	Description	Qty
1	200105514	LIGHT JUNCTION BOX BRACKET	1
2	200105515	LIGHT BRACKET	2
3	200106328	RIG LIGHTING GUARD	1
4	800100189	RELAY JUNCTION BOX 100X100X50 (IP65) ASSEMBLY	1
5	800100252	STRAIN RELIEF GROMMET 9.5MM	1
6	800100263	PVC CABLE GROMMET (INNER DIA 6.4 WITH 10MM PANEL DIA)	4
7	C100G00912	M10 S.S. HEX SOC BUTTON HEAD SCREW X 30 LG	4
8	C108G0083	WORK LAMP 6 X LED 12/24 Volt	2
9	ST01048X881	M10 PLAIN WASHER	12
10	ST01109X510	M10 NYLOC NUT	8
11	ST01146X885	M8 SPRING WASHER	4
12	ST02091X511	M8 THIN NUT	4
13	ST04148X511	M5 FULL NUT	4
14	ST04149X885	M5 SPRING WASHER	4
15	ST07305X133	M10 HEX HD BOLT HT x 30 LONG	4
16	ST09754X883	M5 PLAIN WASHER (BRIGHT)	1
17	ST09755X510	M5 NYLOC NUT	1
18	ST09902X478	SHOCK ABSORBER - BUFFER TYPE A 30/20-M8 x 20 NR 57 SHORE A	2
19	ST10131X788	M5 SCREW PAN HEAD RECESSED x 20 LONG	1
20	ST11135X788	M5 SCREW PAN HEAD RECESSED x 15 LONG	4
21	ST11197X163	6mm "P" CLIP RUBBER LINED JCS	1

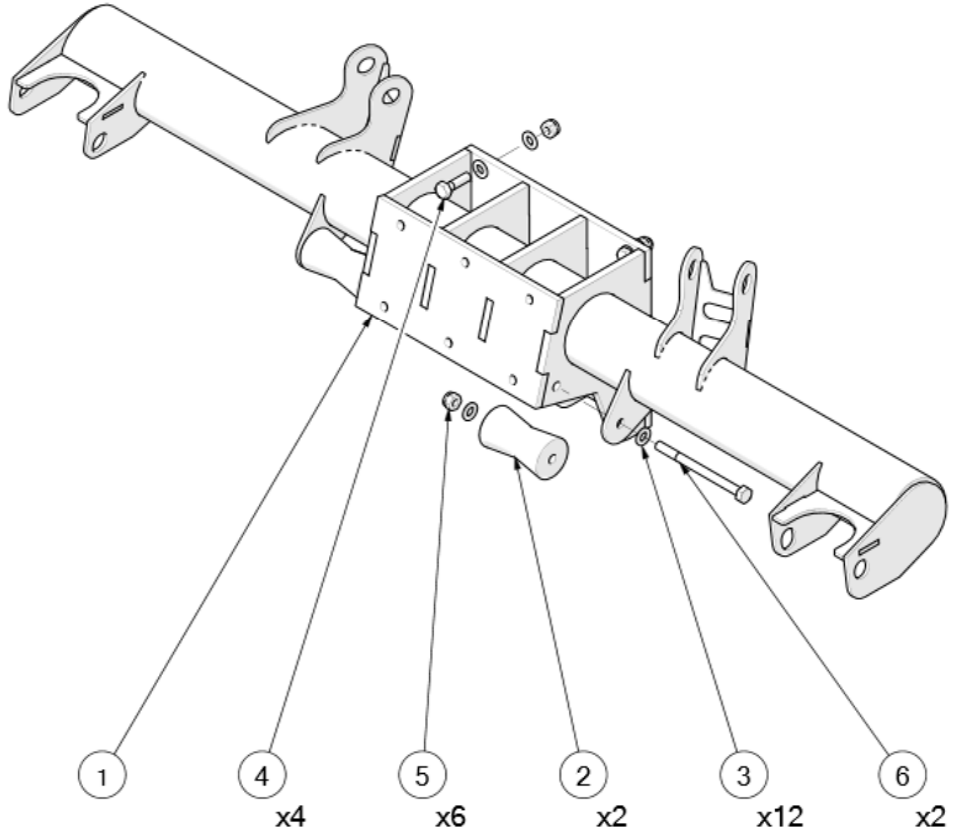
200105715 0.44 TONNE WINCH ASSEMBLY [NP05 - DANDO DUKE]



200105715 0.44 TONNE WINCH ASSEMBLY [NP05 - DANDO DUKE]

BOM ID	Number	Description	Qty
1	200105527	TOOLING WINCH MOUNTING PLATE [MACHINED]	1
2	200115322	0.99T WIRE ROPE ASSEMBLY - 8MM DIA WIRELINE ROTATION RESISTANT X 20M C/W THIMBLE SWAGED END & 2.5T SAFETY SWIVEL HOOK	1
3	910100230	0.44 TONNE WINCH ASSY [NP05]	1
4	ST00777X885	M10 SPRING WASHER	4
5	ST01048X881	M10 PLAIN WASHER	4
6	ST01083X133	M10 HEX HEAD BOLT HT x 35 LG	2
7	ST01084X133	M10 HEX HEAD BOLT HT x 40 LG.	6
8	ST01109X510	M10 NYLOC NUT	4

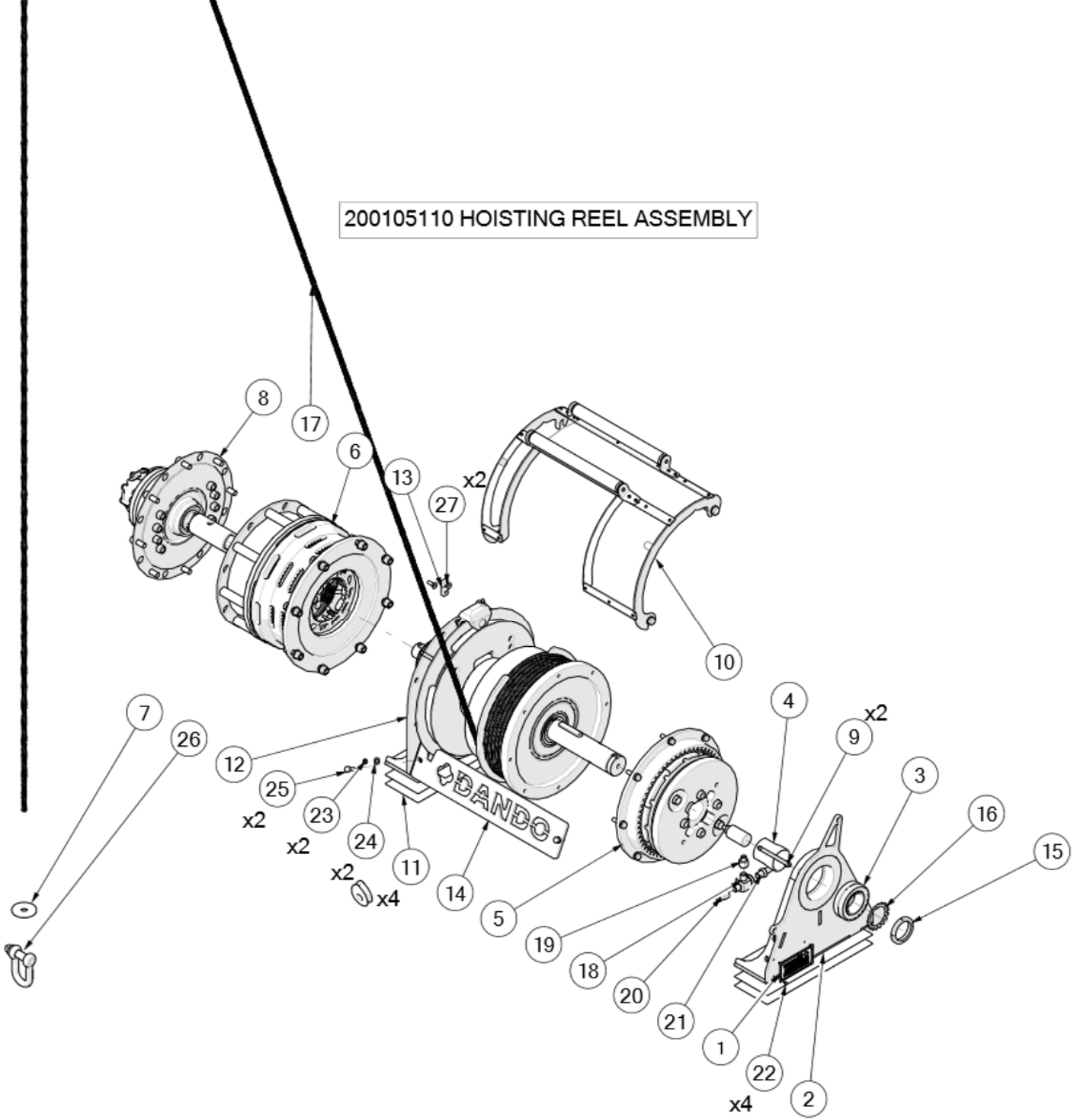
200105963 TIE BAR SUPPORT ASSEMBLY



200105963 TIE BAR SUPPORT ASSEMBLY

BOM ID	Number	Description	Qty
1	200105937	TIE BAR SUPPORT FABRICATION	1
2	900100259	V TYPE RUBBER ROLLER 90mm LG x 11mm BORE	2
3	ST01048X881	M10 PLAIN WASHER	12
4	ST01083X133	M10 HEX HEAD BOLT HT x 35 LG	4
5	ST01109X510	M10 NYLOC NUT	6
6	ST05092X133	M10 HEX HD SET SCREW x 130 LG.	2

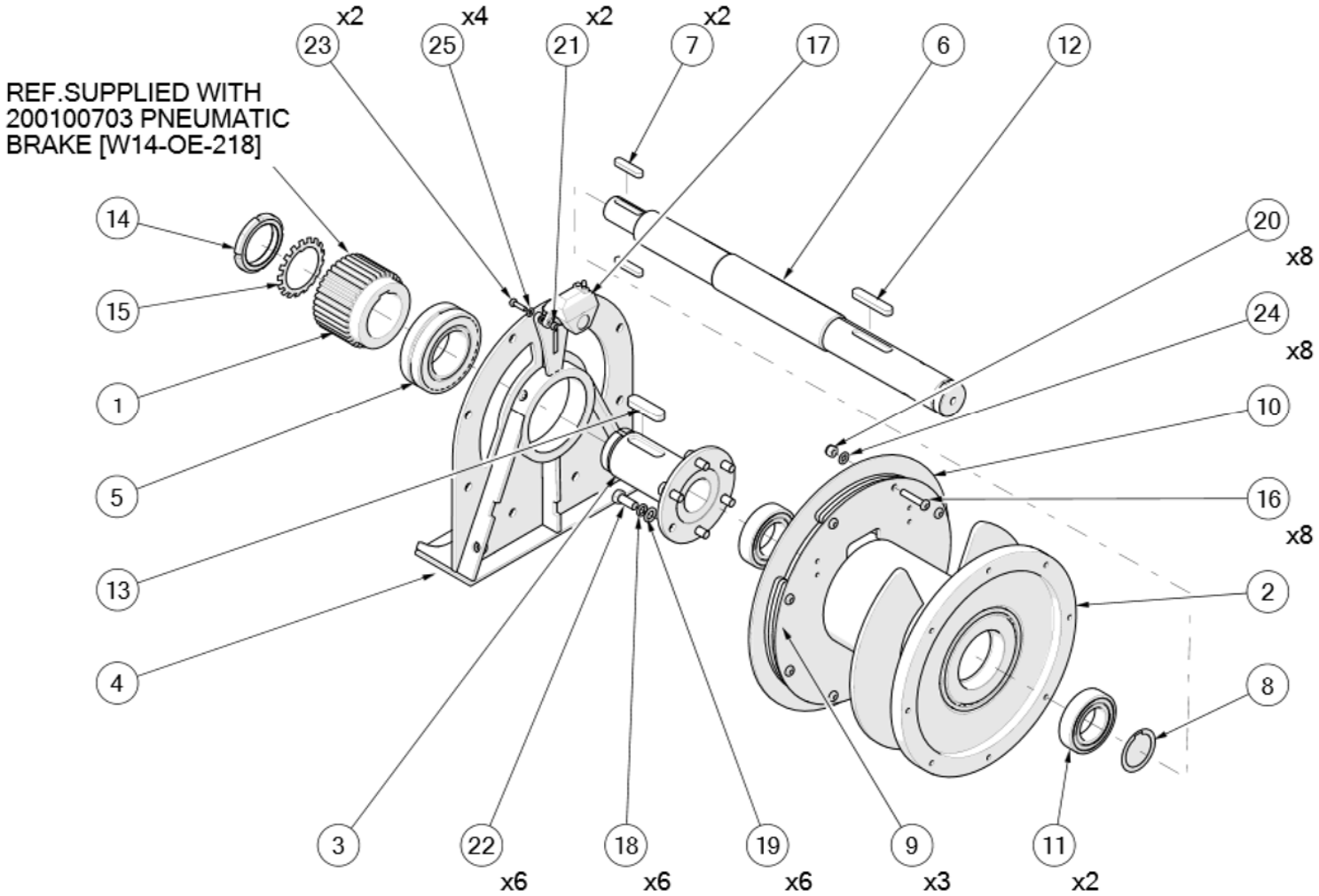
200105110 HOISTING REEL ASSEMBLY



200105110 HOISTING REEL ASSEMBLY

BOM ID	Number	Description	Qty
1	200100100	DANDO SERIAL PLATE [BLANK]	1
2	200105124	BEARING MOUNT MACHINED	1
3	200105127	70 ID 125 OD SPHERICAL ROLLER BEARING (BS2-2214-2RS)	1
4	200105130	CLUTCH HUB SPACER	1
5	200105132	CLUTCH ASSEMBLY	1
6	200105133	BRAKE ASSEMBLY	1
7	200105502	WIRELINE COLLAR	1
8	200105795	MOTOR ASSY	1
9	200108466	GREASER EXTENSION ASSEMBLY	2
10	200108490	HOISTING DRUM SAFETY GUARD ASSEMBLY [STAGE 5]	1
11	200115135	HOISTING REEL SHIM [1MM]	4
12	200115141	HOISTING DRUM ASSEMBLY	1
13	200115147	LINE CLAMP [TAPPED HOLES]	1
14	200115603	WIRELINE RETAINING PLATE	1
15	910100224	M70 LOCKNUT [KM14]	1
16	910100225	M70 LOCK WASHER [MB14]	1
17	910100375	16 DIA WIRELINE [LH LAY - 90M LONG]	1
18	910102235	WPT QUICK EXHAUST VALVE [W00-10-901]	1
19	910102236	0.375IN MALE NPT - 0.5IN FEMALE NPT ADAPTOR [HOPESPARE - 00842]	1
20	910102237	0.5IN FEMALE NPT - 12MM PUSH IN [HOPESPARE - 2111-2750]	1
21	910102238	0.5IN MALE NPT SILENCER [RS - 822-3992]	1
22	910102244	4.8 DIA S.S. DOME HEAD DRIVE RIVET	4
23	ST00777X885	M10 SINGLE COIL SPRING WASHER	2
24	ST05104X883	M10 PLAIN BRIGHT WASHER	2
25	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	2
26	ST09420X729	3 TON "D" SHACKLE	1
27	ST11009X763	M10 SOC HEAD C/SK SCREW x 30 LONG	2

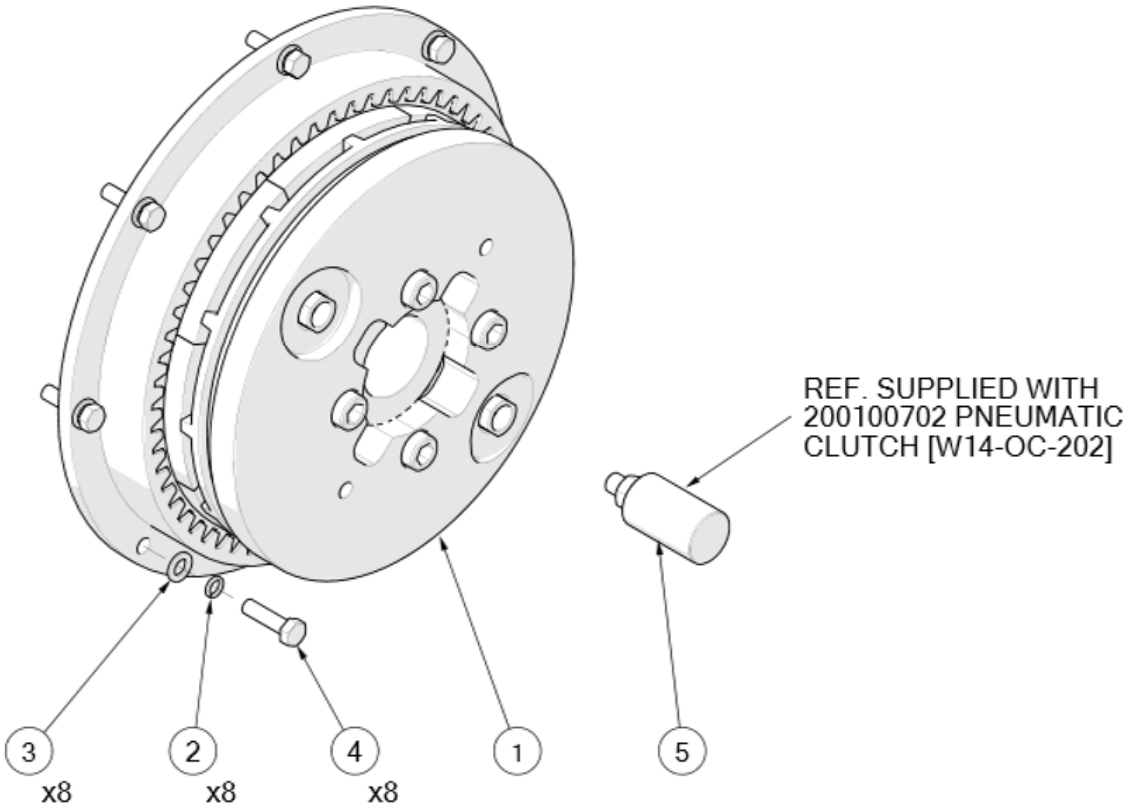
200105131 HOISTING DRUM ASSEMBLY



200105131 HOISTING DRUM ASSEMBLY

BOM ID	Number	Description	Qty
1	200100703 - HUB ONLY	PNEUMATIC BRAKE [W14-OE-218]	1
2	200105100	HOISTING DRUM FABRICATION	1
3	200105111	BRAKE ADAPTOR	1
4	200105114	BRAKE MOUNT MACHINED	1
5	200105115	95 ID 170 OD SPHERICAL ROLLER BEARING (BS2-2219-2RS)	1
6	200105123	HOISTING REEL DRIVE SHAFT	1
7	200105634	16 x 10 x 70 PARALLEL KEY	2
8	200105731	CLUTCH SHIM [1MM]	1
9	200105981	DISC SPACER [10MM]	3
10	200109127	BRAKE DISK [535OD 6THK]	1
11	200390104	70 ID 125 OD CAPPED SINGLE ROW DEEP GROVE BALL BEARING	2
12	200390166	20 x 12 x 100 PARALLEL KEY	1
13	200390167	25 x 14 x 90 PARALLEL KEY	1
14	900101109	M90 LOCKNUT [KM18]	1
15	900101110	M90 LOCK WASHER [MB18]	1
16	900101116	M12 X 60MM SOCKET BUTTON SCREW (ISO 7380) ZINC PLATED 10.9 HARDENED STEEL	8
17	910102220	BRAKE CALIPER	1
18	ST00651X885	M16 SINGLE COIL SPRING WASHER	6
19	ST00656X881	M16 ORDINARY WASHER	6
20	ST00787X510	M12 NYLOC NUT	8
21	ST01123X511	M8 FULL NUT	2
22	ST07327X715	M16 HEX HEAD SET SCREW HT x 40 LONG	6
23	ST07885X715	M8 HEX HEAD HT SET SCREW x 30 LG.	2
24	ST09900X883	M12 PLAIN BRIGHT WASHER	8
25	ST10249X883	M8 PLAIN BRIGHT WASHER	4

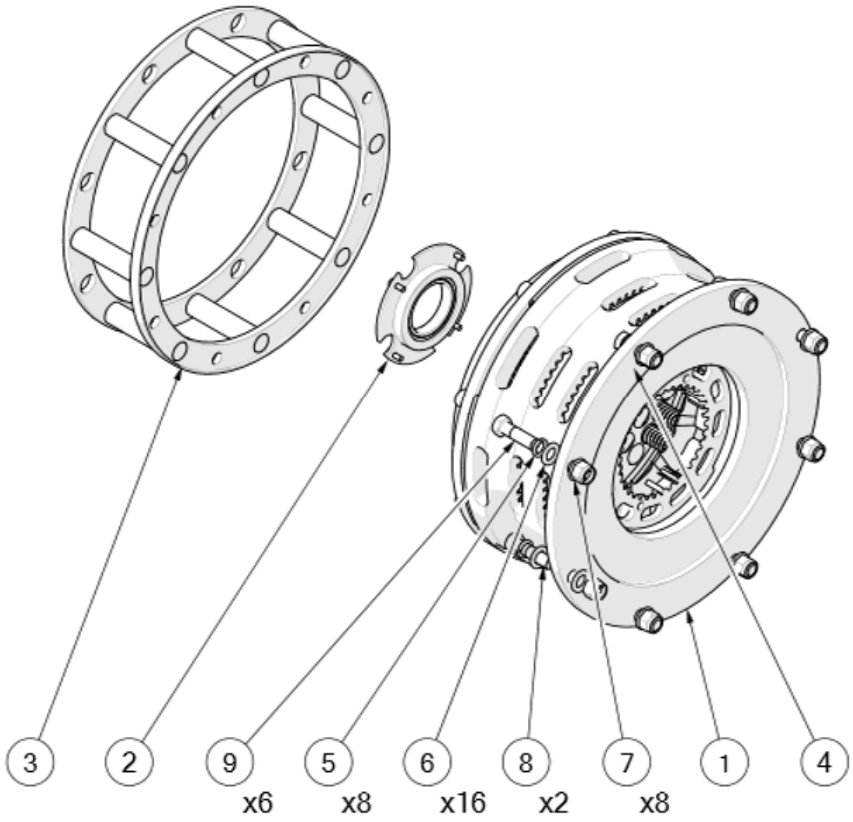
200105132 CLUTCH ASSEMBLY



200105132 CLUTCH ASSEMBLY

BOM ID	Number	Description	Qty
1	200100702	PNEUMATIC CLUTCH [W14-OC-202]	1
2	ST00648X885	M12 SPRING WASHER - SINGLE COIL	8
3	ST00788X881	M12 PLAIN WASHER	8
4	ST05459X715	M12 SET SCREW HEX HD HT x 45 LONG	8
5	W00-21-001	ROTARY UNION	1

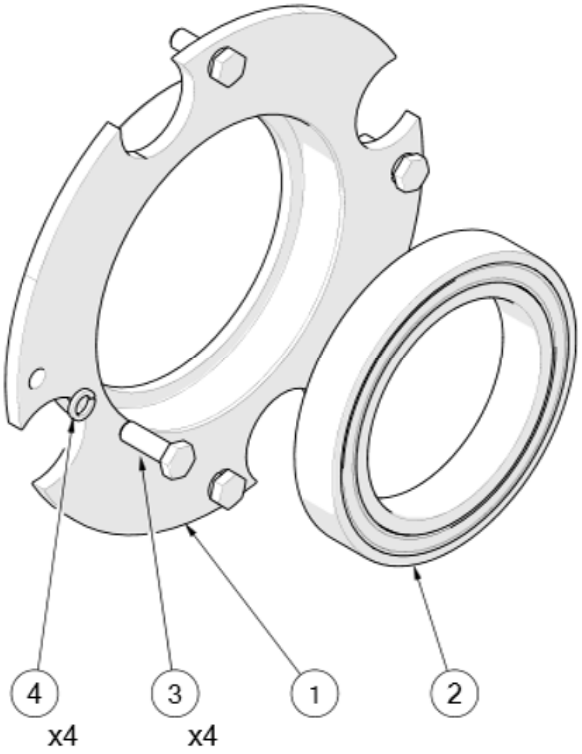
200105133 BRAKE ASSEMBLY



200105133 BRAKE ASSEMBLY

BOM ID	Number	Description	Qty
1	200100703	PNEUMATIC BRAKE [W14-OE-218]	1
2	200105204	BRAKE BEARING ASSY	1
3	200105210	MOTOR HOUSING (CAGE)	1
4	C10000590	0.5in NPTF - 0.5in BSP MALE-MALE	1
5	ST00651X885	M16 SINGLE COIL SPRING WASHER	8
6	ST00656X881	M16 ORDINARY WASHER	16
7	ST00934X510	M16 NYLOC NUT	8
8	ST01118X133	M16 HEX HEAD BOLT HT x 60 LG.	2
9	ST10284X133	M16 HEX HEAD BOLT HT x 55 LONG.	6

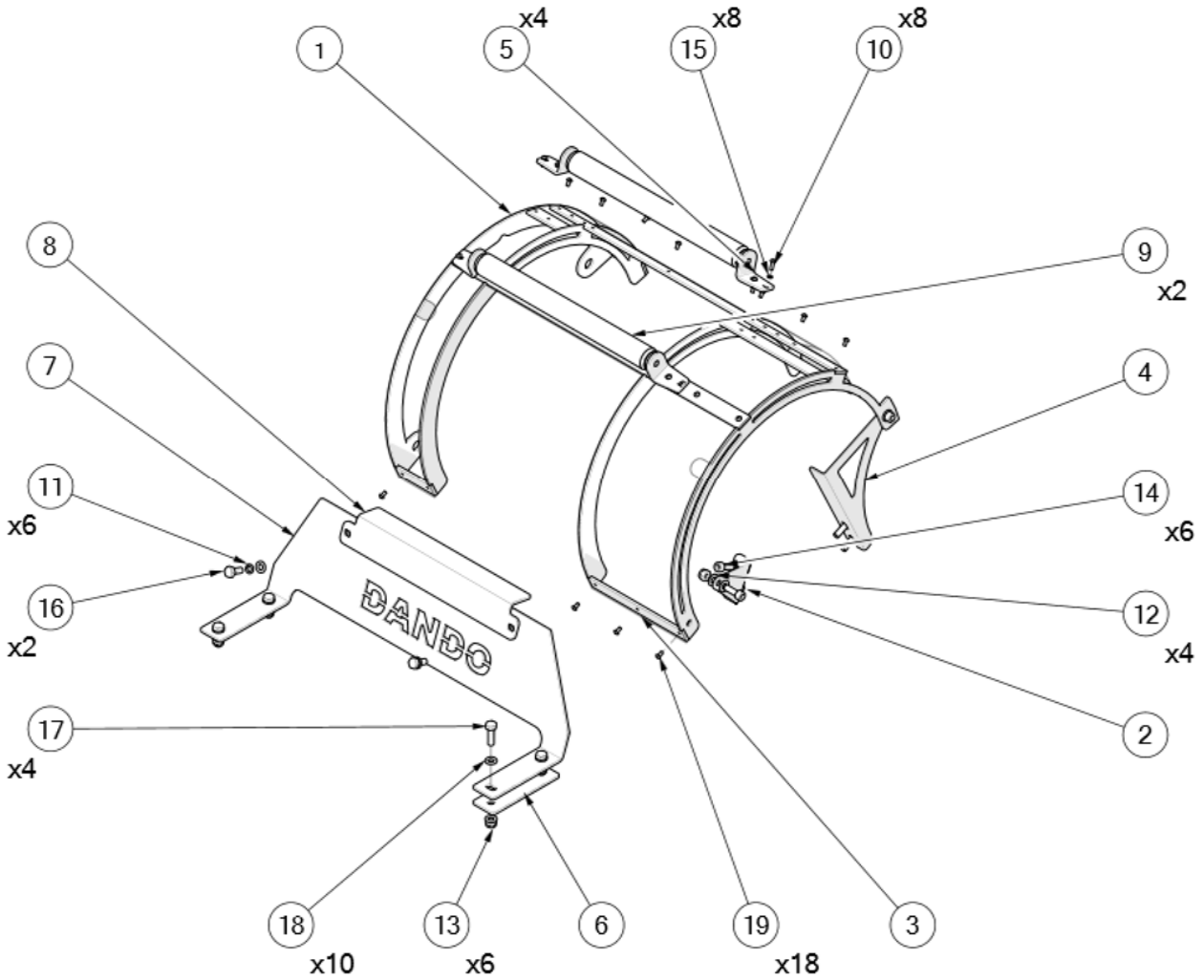
200105204 BRAKE BEARING ASSEMBLY



200105204 BRAKE BEARING ASSEMBLY

BOM ID	Number	Description	Qty
1	200105203	BRAKE BEARING HOUSING	1
2	910100201	RADIAL BALL BEARING (CAPPED) 70 ID X 100 OD X 16 LG [61914-2RZ]	1
3	C10001136	1/4" UNC HEX HEAD BOLT X 3/4" LONG HT	4
4	ST01179X885	M6 SPRING WASHER	4

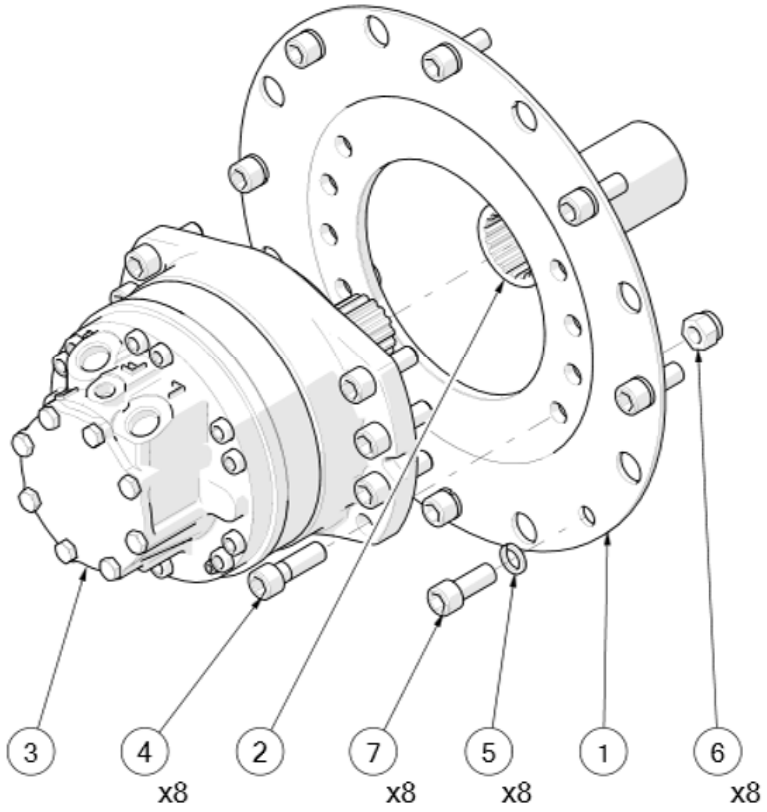
200105555 DRUM SAFETY GUARD ASSEMBLY



200105555 DRUM SAFETY GUARD ASSEMBLY

BOM ID	Number	Description	Qty
1	200105556	DRUM SAFETY GUARD FAB	1
2	200105565	DRUM SAFETY GUARD BRACKET	1
3	200105566	DRUM SAFETY GUARD MESH	1
4	200105568	DRUM SAFETY GUARD BRACKET	1
5	200108333	MOUNING BRACKET - GUARD ROLLER	4
6	200108335	SPACER - LINE GUIDE	1
7	200108336	ROLLER BRACKET FABRICATION - LINE GUIDE	1
8	200108337	LINE GUIDE - WINCH GUARD	1
9	900100257	SPRING LOADED ROLLER 40 DIA X 400 LG [RD-17W2JF4HAC RL400]	2
10	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	8
11	ST00777X885	M10 SINGLE COIL SPRING WASHER	6
12	ST01048X881	M10 PLAIN WASHER	4
13	ST01109X510	M10 NYLOC NUT	6
14	ST02177X743	M10 SOCKET HEAD CAP SCREW x 30 LONG	6
15	ST04149X885	M5 SPRING WASHER	8
16	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	2
17	ST09086X715	M10 HEX HEAD SET SCREW HT x 35 LG.	4
18	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	10
19	ST12544X792	M5 SOCKET BUTTON HEADCAP SCREW X 10 LONG [ZINC PLATED]	18

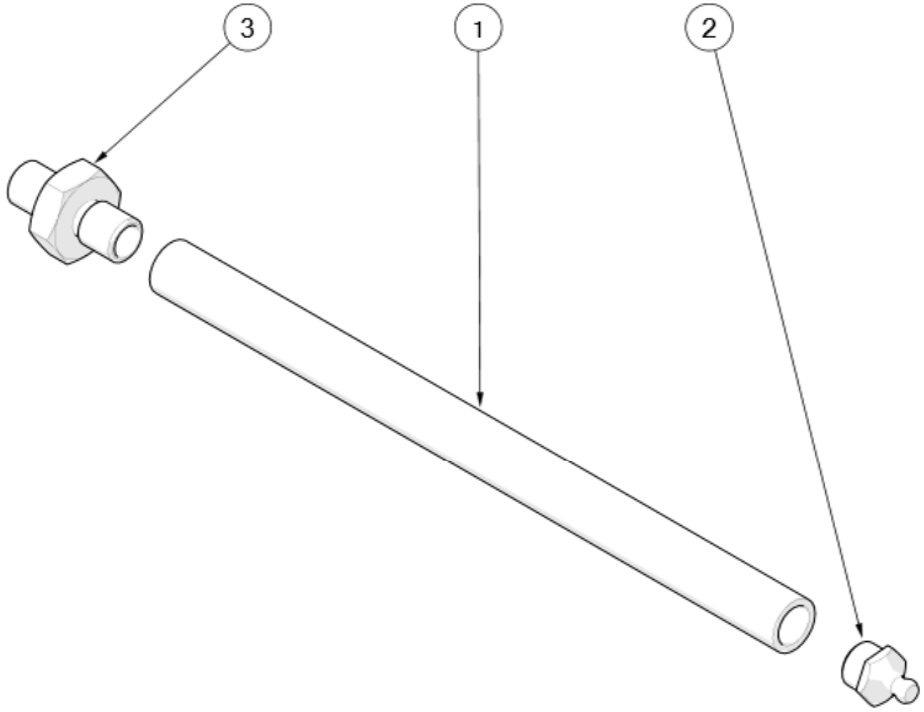
200105795 MOTOR ASSEMBLY



200105795 MOTOR ASSEMBLY

BOM ID	Number	Description	Qty
1	200105470	MOTOR MOUNT PLATE MACHINED	1
2	200105796	MOTOR DRIVE COUPLING [SPLINE / KEYWAY]	1
3	700200188	HYDRAULIC MOTOR RADIAL PISTON 750ccrev	1
4	ST00568X743	M16 SOCKET HEAD CAP SCREW x 50 LONG	8
5	ST00651X885	M16 SINGLE COIL SPRING WASHER	8
6	ST00934X510	M16 NYLOC NUT	8
7	ST01977X743	M16 SOCKET HEAD CAP SCREW x 40 LG.	8

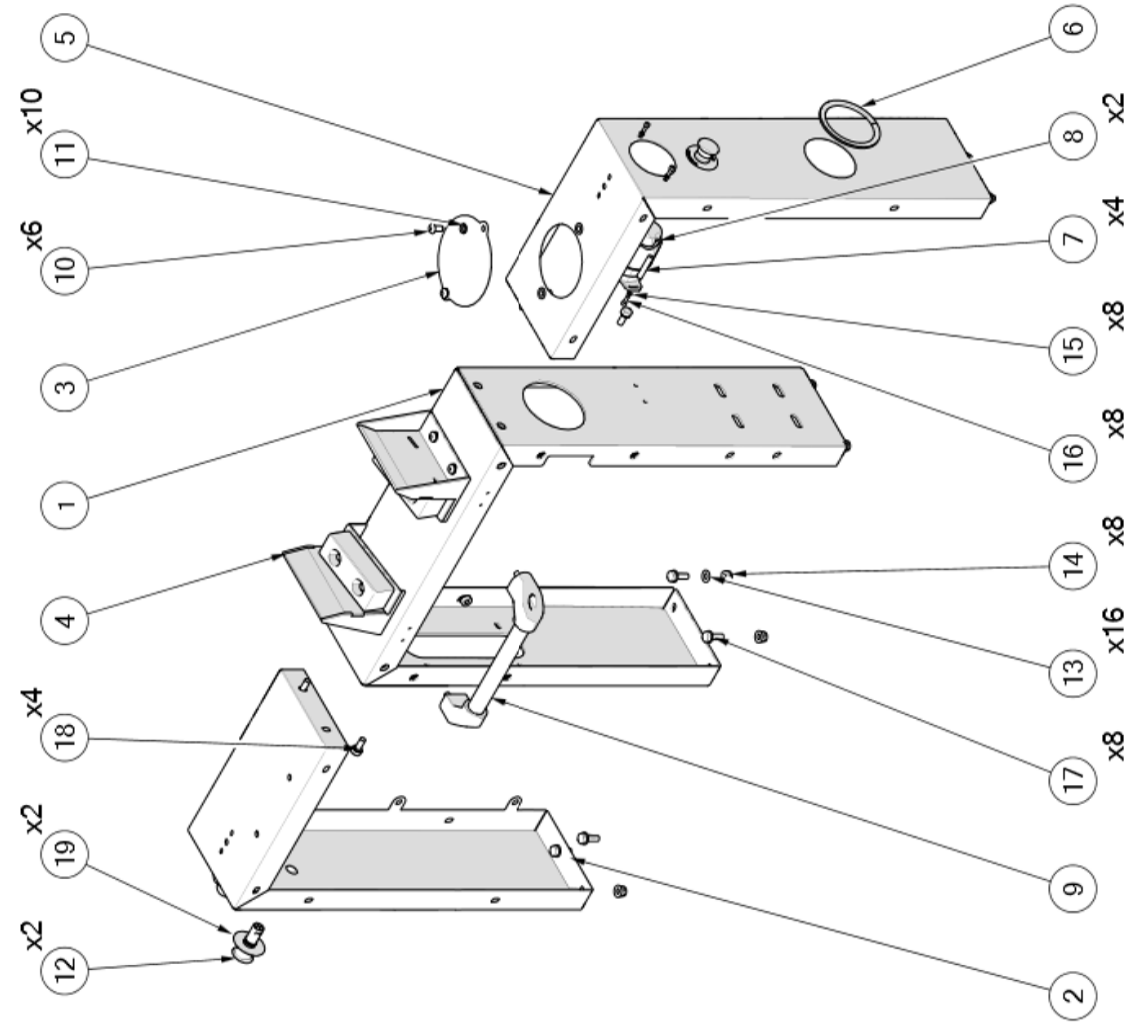
200108466 GREASER EXTENSION ASSEMBLY



200108466 GREASER EXTENSION ASSEMBLY

BOM ID	Number	Description	Qty
1	200108465	GREASE EXTENSION	1
2	ST00180X270	1/8" BSP STR GREASE NIPPLE	1
3	ST02204X326	1/8" BSP - 1/8" BSP MALE/MALE STUD ADAPTOR	1

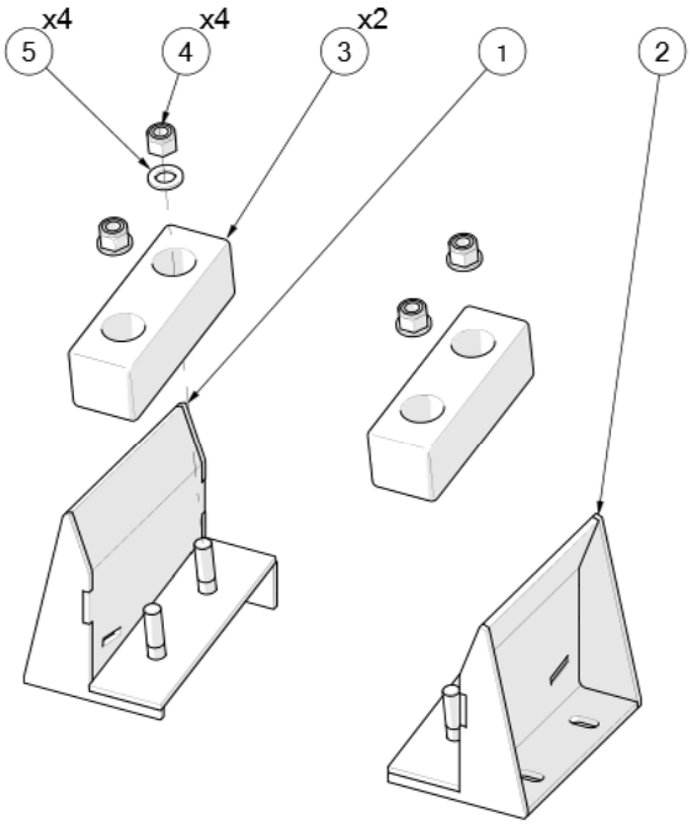
200105191 HEADACHE POST ASSEMBLY



200105191 HEADACHE POST ASSEMBLY

BOM ID	Number	Description	Qty
1	200105174	HEADACHE POST FABRICATION	1
2	200105178	HEADACHE POST CANOPY OS	1
3	200105338	COVER PLATE	1
4	200105348	HEADACHE POST SEAT ASSEMBLY	1
5	200105520	HEADACHE POST CANOPY NS ASSEMBLY	1
6	200105615	AIR PTO EDGING TRIM	1
7	200106434	BEACON MOUNT	4
8	800100164	SOUND BEACON WITH AMBER LIGHT	2
9	900100149	TUBED HANDLE WITCH HANDLE WITH STAINLESS STEEL GRIP	1
10	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	6
11	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	10
12	C100X0166	COMPACT E-STOP	2
13	ST01048X881	M10 PLAIN WASHER	16
14	ST01109X510	M10 NYLOC NUT	8
15	ST04149X885	M5 SPRING WASHER	8
16	ST06149X743	M5 SOCKET HEAD CAP SCREW x 15 LG	8
17	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	8
18	ST10142X133	M10 HEX HD BOLT HT x 25 LONG	4
19	ST10288X224	EMERGENCY STOP LEGEND PLATE	2

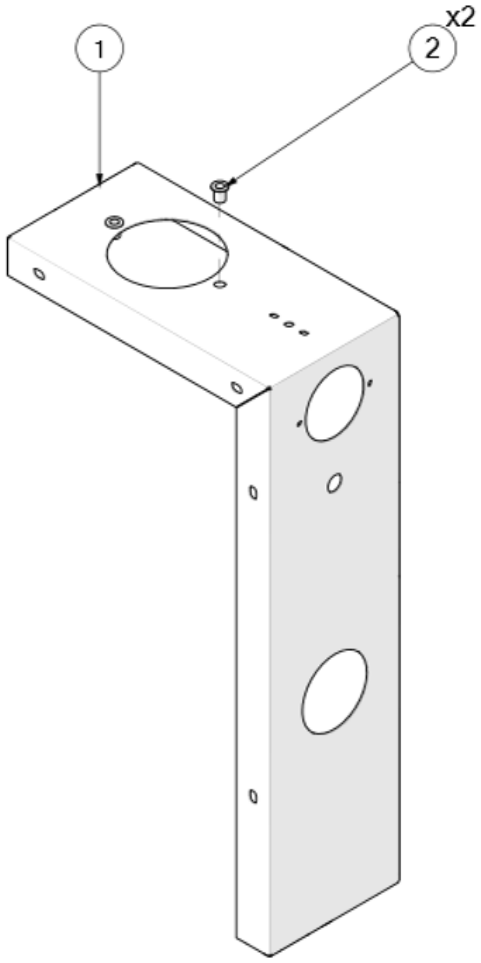
200105348 HEADACHE POST SEAT ASSEMBLY



200105348 HEADACHE POST SEAT ASSEMBLY

BOM ID	Number	Description	Qty
1	200105349	HEADACHE POST SEAT L/H FABRICATION	1
2	200105350	HEADACHE POST SEAT R/H FABRICATION	1
3	C100G01629	RUBBER BUFFER 150 x 50 x 50	2
4	ST00787X523	M12 NYLOC NUT - GRADE 10	4
5	ST00788X881	M12 PLAIN WASHER	4

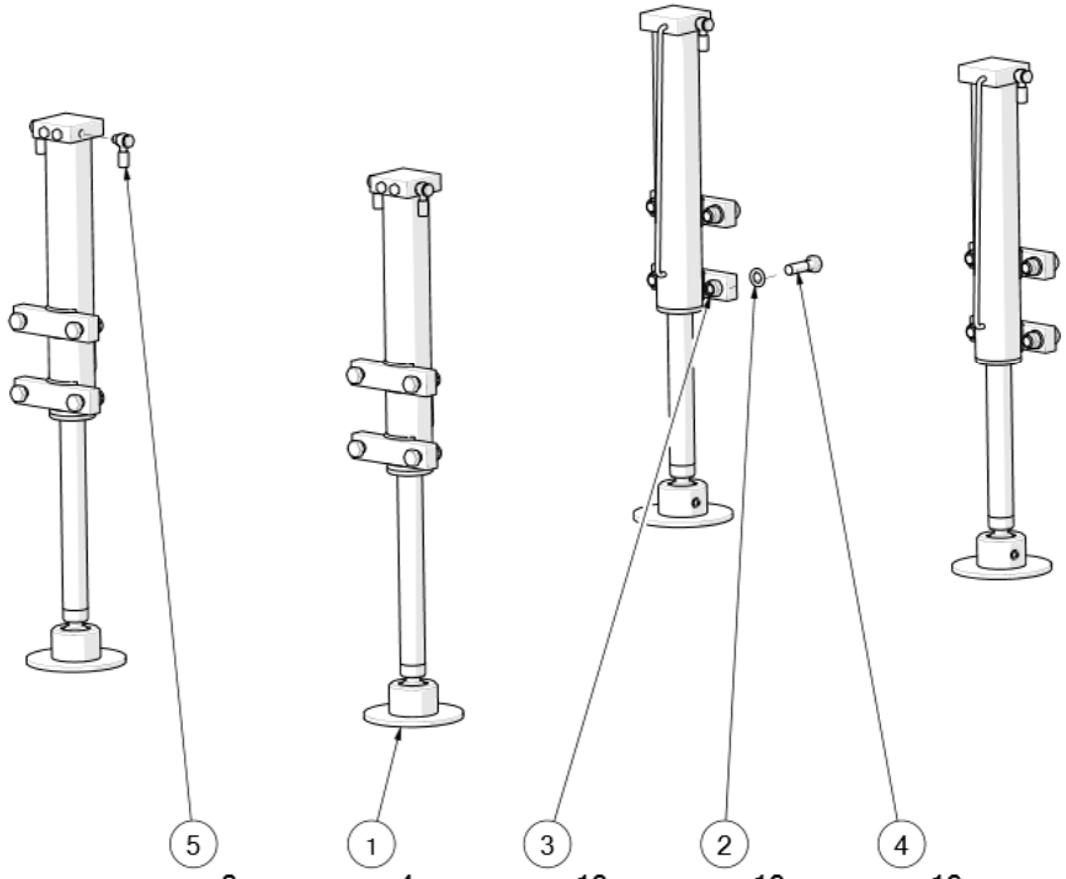
200105520 HEADACHE POST CANOPY NS ASSEMBLY



200105520 HEADACHE POST CANOPY NS ASSEMBLY

BOM ID	Number	Description	Qty
1	200105519	HEADACHE POST CANOPY NS	1
2	910100214	M10 NUTSERT (S.S.)	2

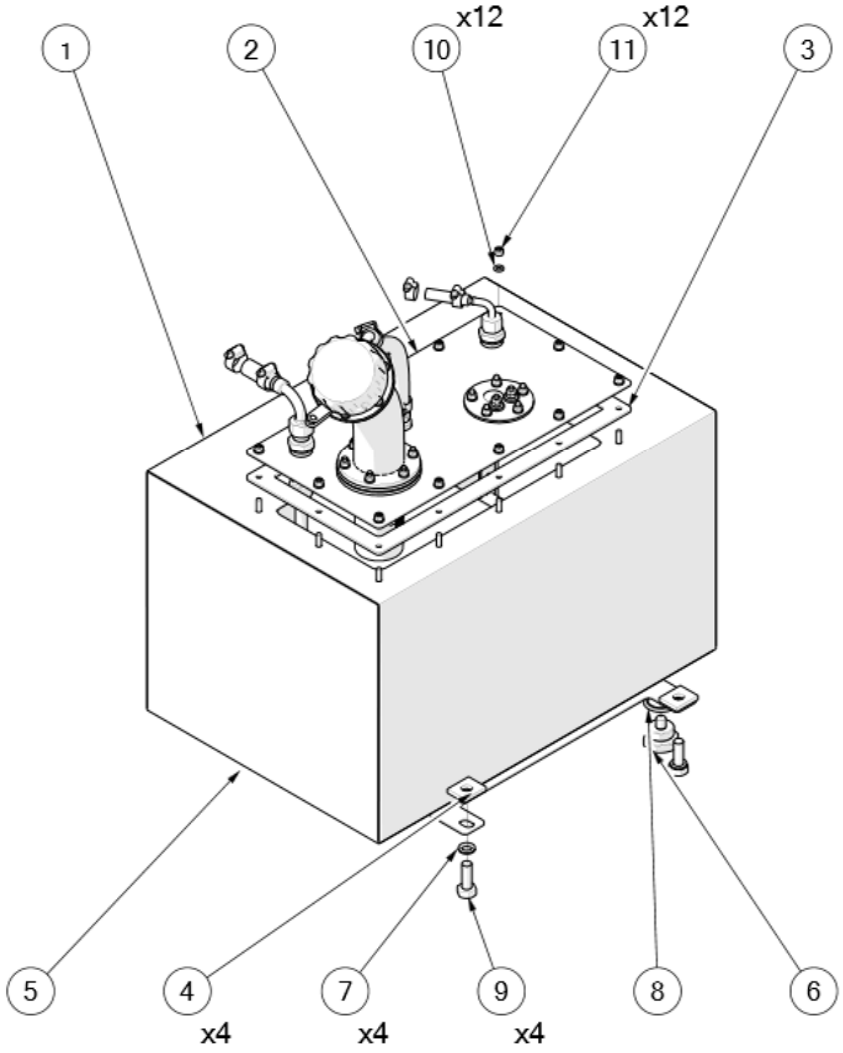
200105171 LEVELLING JACK ASSEMBLY



200105171 LEVELLING JACK ASSEMBLY

BOM ID	Number	Description	Qty
1	200102100	JACK RAM [80 BORE X 50 ROD X 400 STROKE]	4
2	ST00665X881	M20 PLAIN WASHER	16
3	ST00713X510	M20 NYLOC - SELF LOCKING NUT	16
4	ST05094X133	M20 HEX HD BOLT HT x 70 LG.	16
5	ST20102X102	3/8" BSP x 3/8" 2WB SWAGED HOSE END.	8

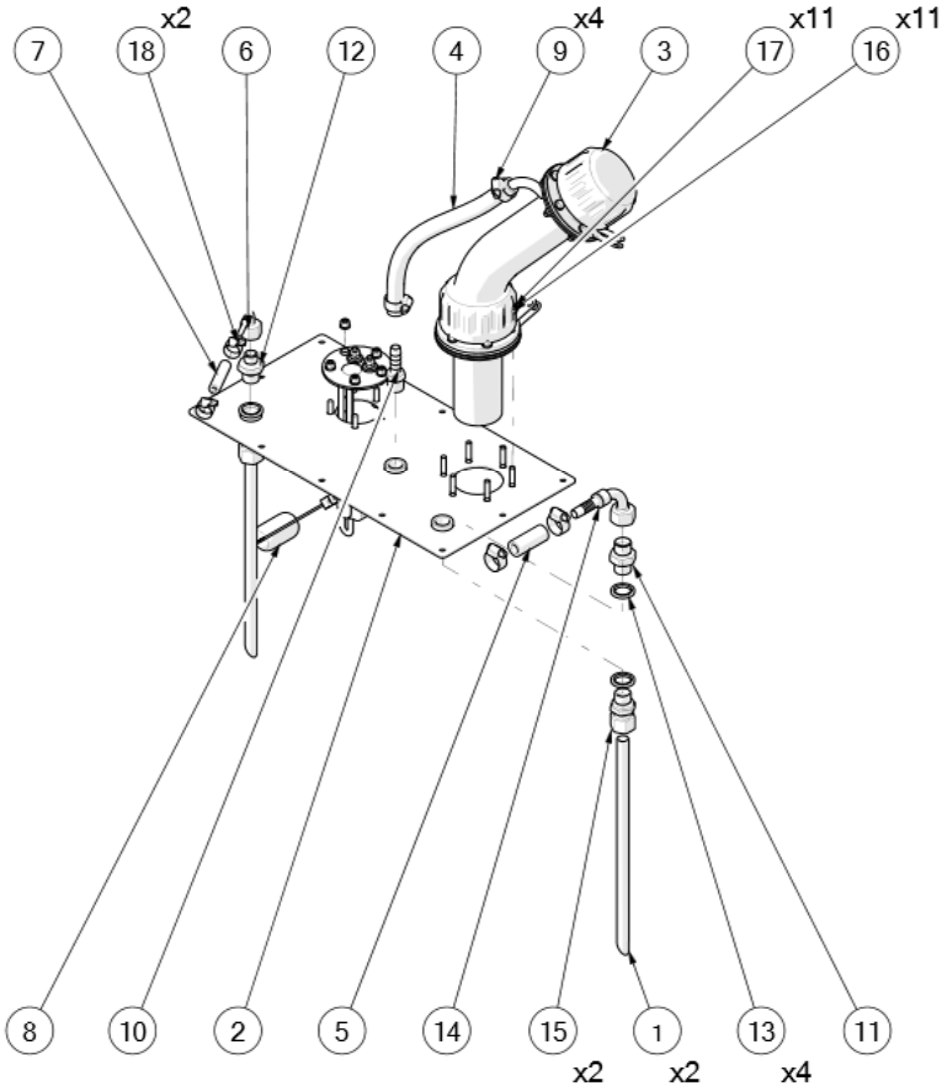
200105357 FUEL TANK ASSEMBLY (44L)



200105357 FUEL TANK ASSEMBLY (44L)

BOM ID	Number	Description	Qty
1	200105190	44L FUEL TANK FABRICATION	1
2	200105358	FUEL TANK LID ASSEMBLY	1
3	200105362	GASKET (FUEL TANK)	1
4	200105363	RUBBER CUSHION (FUEL TANK)	4
5	200105627	FUEL - DUKE FUEL TANK	1
6	900100105	0.75 INCH BSP HEX HEAD MAGNETIC PLUG	1
7	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	4
8	ST00148X328	3/4" NB BONDED SEAL	1
9	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	4
10	ST09754X883	M5 PLAIN WASHER - BRIGHT	12
11	ST09755X510	M5 NYLOC NUT	12

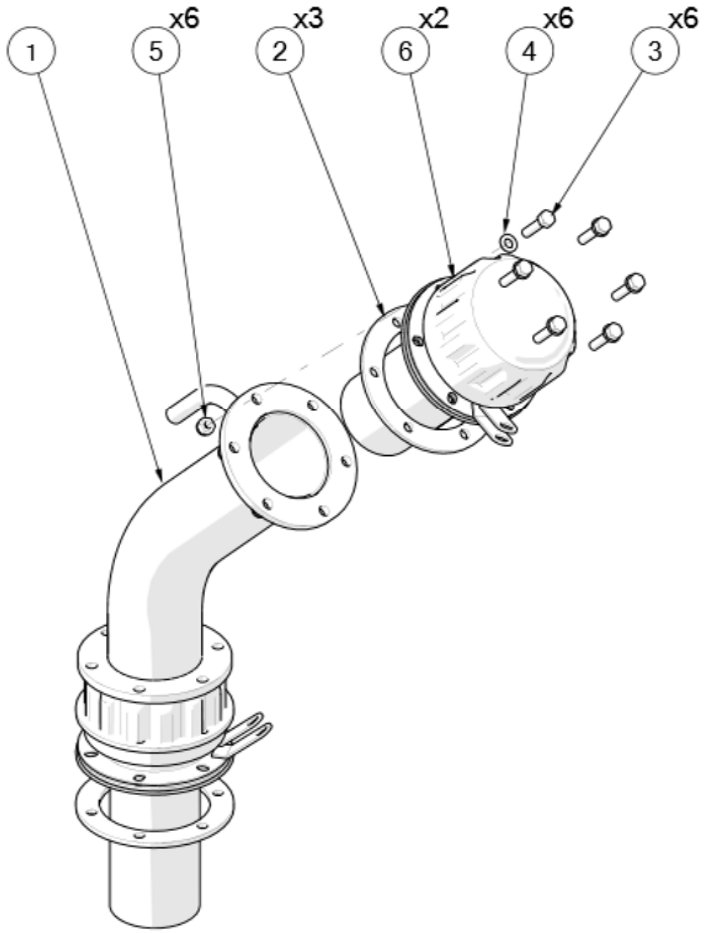
200105358 FUEL TANK LID ASSEMBLY



200105358 FUEL TANK LID ASSEMBLY

BOM ID	Number	Description	Qty
1	13130250015	12 x 1.5 hyd pipe x 260 LG	2
2	200105359	FUEL TANK LID FABRICATION	1
3	200105365	FILLER ASSEMBLY (44L FUEL TANK)	1
4	90730190000-250	10mm ID x 17mm OD (RUBBER FUEL HOSE - SAEJ30R6) x 250 LG	1
5	90730190000-500	10mm ID x 17mm OD (RUBBER FUEL HOSE - SAEJ30R6) x 500 LG	1
6	910102234	0.25IN BSP SWIVEL FEMALE SWEPT 90 DEG HOSE TAIL (0.1875IN ID)	1
7	C1000033-1500	Fuel Hose 3/16" ID x 1500LG	1
8	C100C0086	FUEL LEVEL SENDER UNIT (ES2F 2-WIRE RESISTIVE)	1
9	C1050113	13-20 mm JUBILEE CLIP (S.E.H. NUMBER WD13/20)	4
10	C115C0052	3/8"BSPT MALE TO 3/8" BORE STEEL HOSE TAIL	1
11	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	1
12	ST01155X326	1/4"BSP TO 3/8"BSP MALE/MALE STUD ADAPTER	1
13	ST01156X328	3/8"BSP BONDED SEAL	4
14	ST01892X332	3/8" BSP SWIVEL FEMALE SWEPT 90 DEG (HOSE TAIL)	1
15	ST08823X298	3/8" BSP x 12mm OD PARALLEL MALE STUD COUPLING	2
16	ST09754X883	M5 PLAIN WASHER - BRIGHT	11
17	ST09755X510	M5 NYLOC NUT	11
18	ST20248X999	3.5-12MM JUBILEE CLIP	2

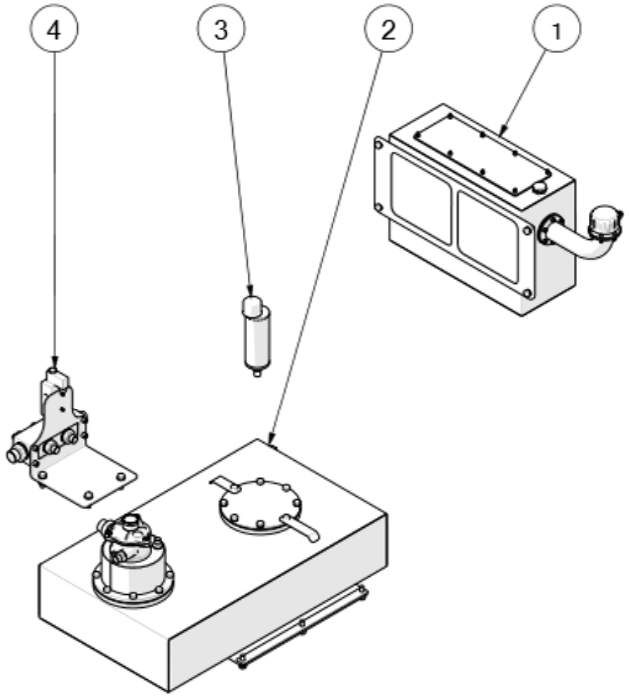
200105365 FILLER ASSEMBLY (44L FUEL TANK)



200105365 FILLER ASSEMBLY (44L FUEL TANK)

BOM ID	Number	Description	Qty
1	C002C0131143	FUEL FILLER EXTENSION	1
2	C002C013276	GASKET - FILLER/BREATHER (3mm THICK NEOPRENE RUBBER)	3
3	ST01952X715	M5 HEX HEAD SET SCREW HT x 20 LONG	6
4	ST09754X883	M5 PLAIN WASHER - BRIGHT	6
5	ST09755X510	M5 NYLOC NUT	6
6	ST10132X250	BREATHER/FILLERCAP, LOCKING - PARKER 5515	2

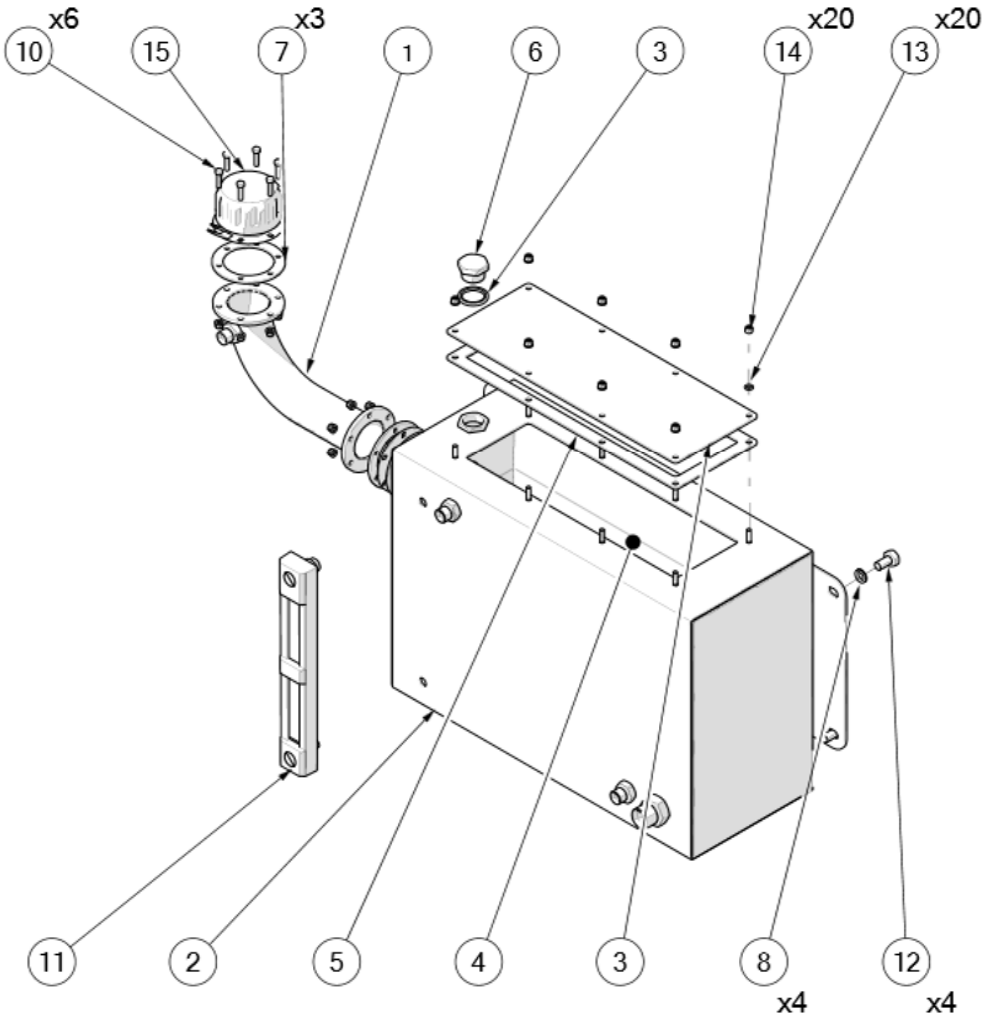
200105783 HYDRAULIC TANKS ASSEMBLY



200105783 HYDRAULIC TANKS ASSEMBLY

BOM ID	Number	Description	Qty
1	200105375	HYDRAULIC HEADER TANK ASSEMBLY	1
2	200105770	HYDRAULIC TANK ASSEMBLY	1
3	200109147	HYDRAULIC TANK BREATHER ASSEMBLY	1
4	200800297	DANDO DUKE RETURN MANIFOLD ASSY	1

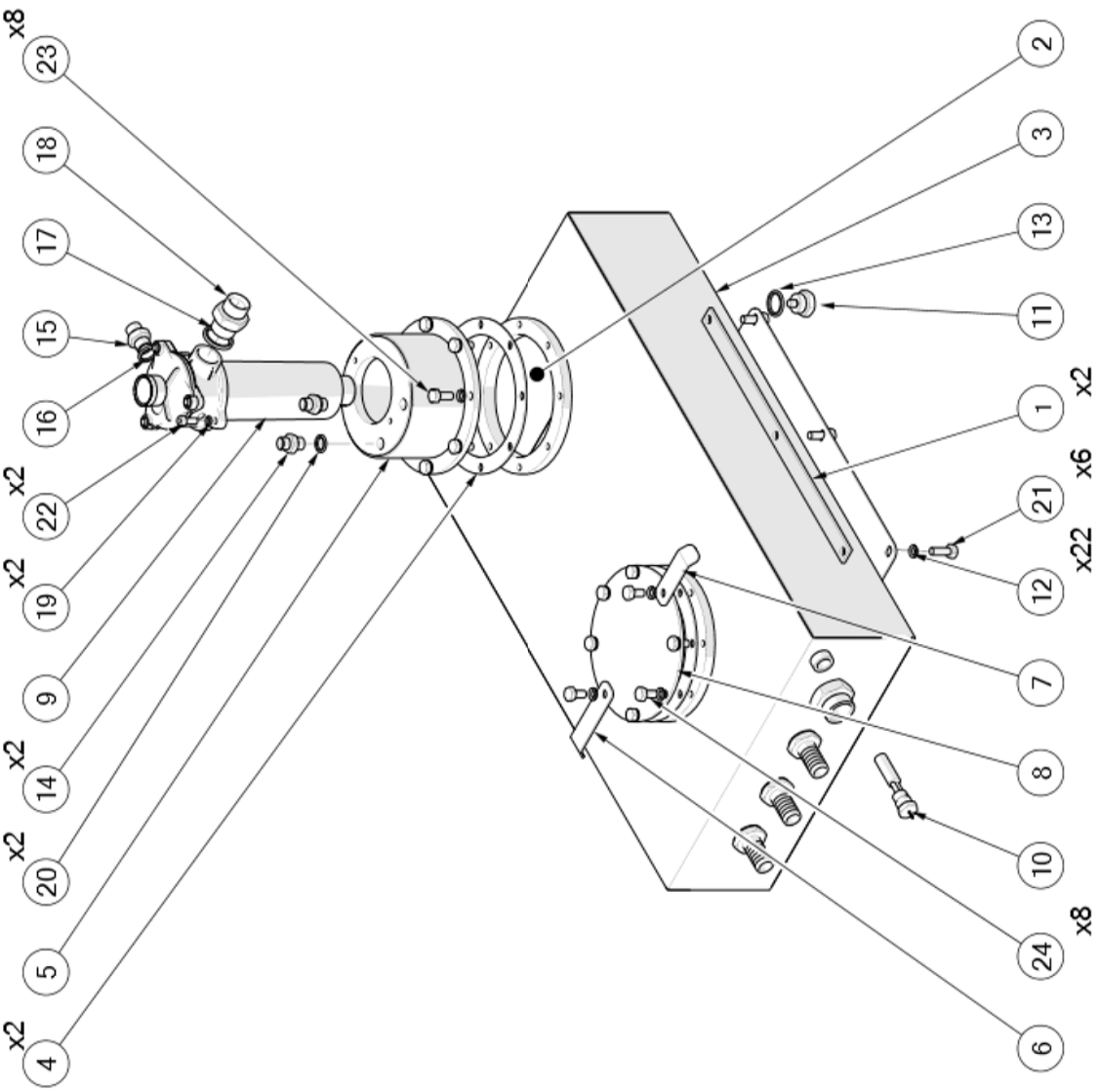
200105375 HYDRAULIC HEADER TANK ASSEMBLY



200105375 HYDRAULIC HEADER TANK ASSEMBLY

BOM ID	Number	Description	Qty
1	200105148	FILLER FABRICATION (HEADER TANK)	1
2	200105374	HYDRAULIC HEADER TANK FABRICATION	1
3	200105376	HYDRAULIC HEADER TANK LID	1
4	200105625	HYD FLUID - DUKE HEADER TANK	1
5	200105791	HEADER TANK GASKET GASKET [NITRILE 70ShA]	1
6	700200183	0.75IN BREATHER PLUG CW 40 MICRON FILTER	1
7	C002C013276	GASKET - FILLER/BREATHER (3mm THICK NEOPRENE RUBBER)	3
8	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	4
9	ST00148X328	3/4" NB BONDED SEAL	1
10	ST01952X715	M5 HEX HEAD SET SCREW HT x 20 LONG	6
11	ST05972X252	LEVEL/TEMPERATURE GAUGE - UC - FLT 321 [PARKER]	1
12	ST08401X715	M10 HEX HEAD SET SCREW HT x 20 LONG.	4
13	ST09754X883	M5 PLAIN WASHER - BRIGHT	20
14	ST09755X510	M5 NYLOC NUT	20
15	ST10132X250	BREATHER/FILLERCAP, LOCKING - PARKER 5515	1

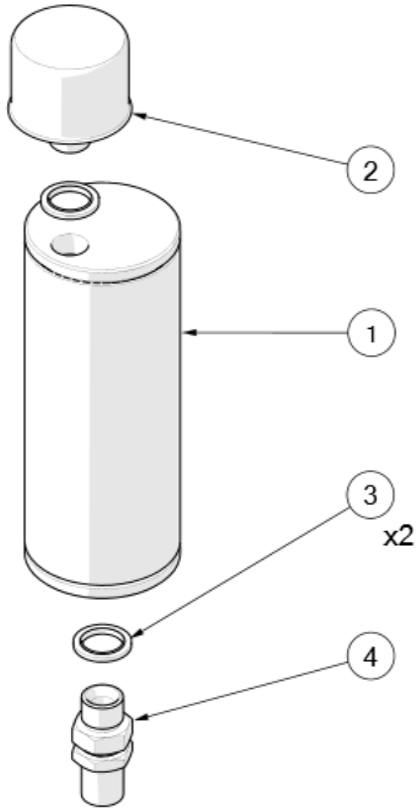
200105770 HYDRAULIC CHASSIS TANK ASSEMBLY



200105770 HYDRAULIC CHASSIS TANK ASSEMBLY

BOM ID	Number	Description	Qty
1	200105347	RUBBER CUSHION MOUNT (HYD OIL TANK)	2
2	200105626	HYD FLUID - DUKE HYD TANK	1
3	200105771	HYDRAULIC MAIN TANK FABRICATION	1
4	200105789	FLANGE GASKET [NITRILE 70ShA]	2
5	200105980	HYDRAULIC RETURN FILTER - MACHINED	1
6	200108373	HOSE SUPPORT - CLUTCH SIDE	1
7	200108374	HOSE SUPPORT - BRAKE SIDE	1
8	200109133	INSPECTION LID [MACHINED]	1
9	700100115	RETURN FILTER TANK TOP 100L/MIN 10 MICRON	1
10	800100269	HORIZONTAL MOUNTING FLOAT LEVEL SWITCH	1
11	900100105	0.75 INCH BSP HEX HEAD MAGNETIC PLUG	1
12	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	22
13	ST00148X328	3/4" BSP BONDED SEAL	1
14	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	2
15	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	1
16	ST00246X328	1/2" BSP BONDED SEAL	1
17	ST00300X328	1" BSP BONDED SEAL	1
18	ST00395X326	1" BSP MALE STUD ADAPTOR	1
19	ST01146X885	M8 SPRING WASHER SINGLE COIL	2
20	ST01156X328	3/8"BSP BONDED SEAL	2
21	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	6
22	ST06590X743	M8 SOCKET HEAD CAP SCREW x 20 LG	2
23	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	8
24	ST08401X715	M10 HEX HEAD SET SCREW HT x 20 LONG.	8

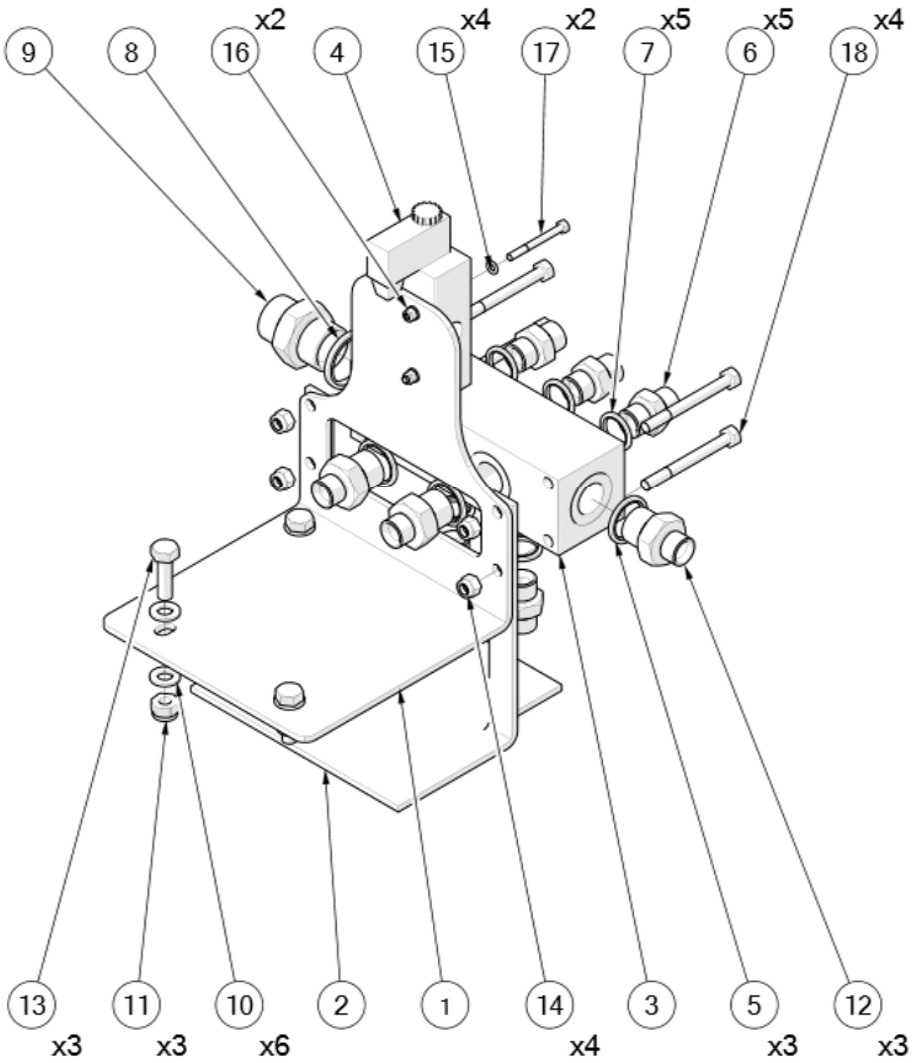
200109147 HYDRAULIC TANK BREATHER ASSEMBLY



200109147 HYDRAULIC TANK BREATHER ASSEMBLY

BOM ID	Number	Description	Qty
1	200109150	TANK BREATHER FAB	1
2	910102256	AIR BREATHER FILTER [FLOWFIT FB110B2C40]	1
3	ST01156X328	3/8"BSP BONDED SEAL [DOWTY]	2
4	ST08827X315	3/8" BSP MALE/MALE [60° CONE] BULKHEAD C/W LOCK NUT	1

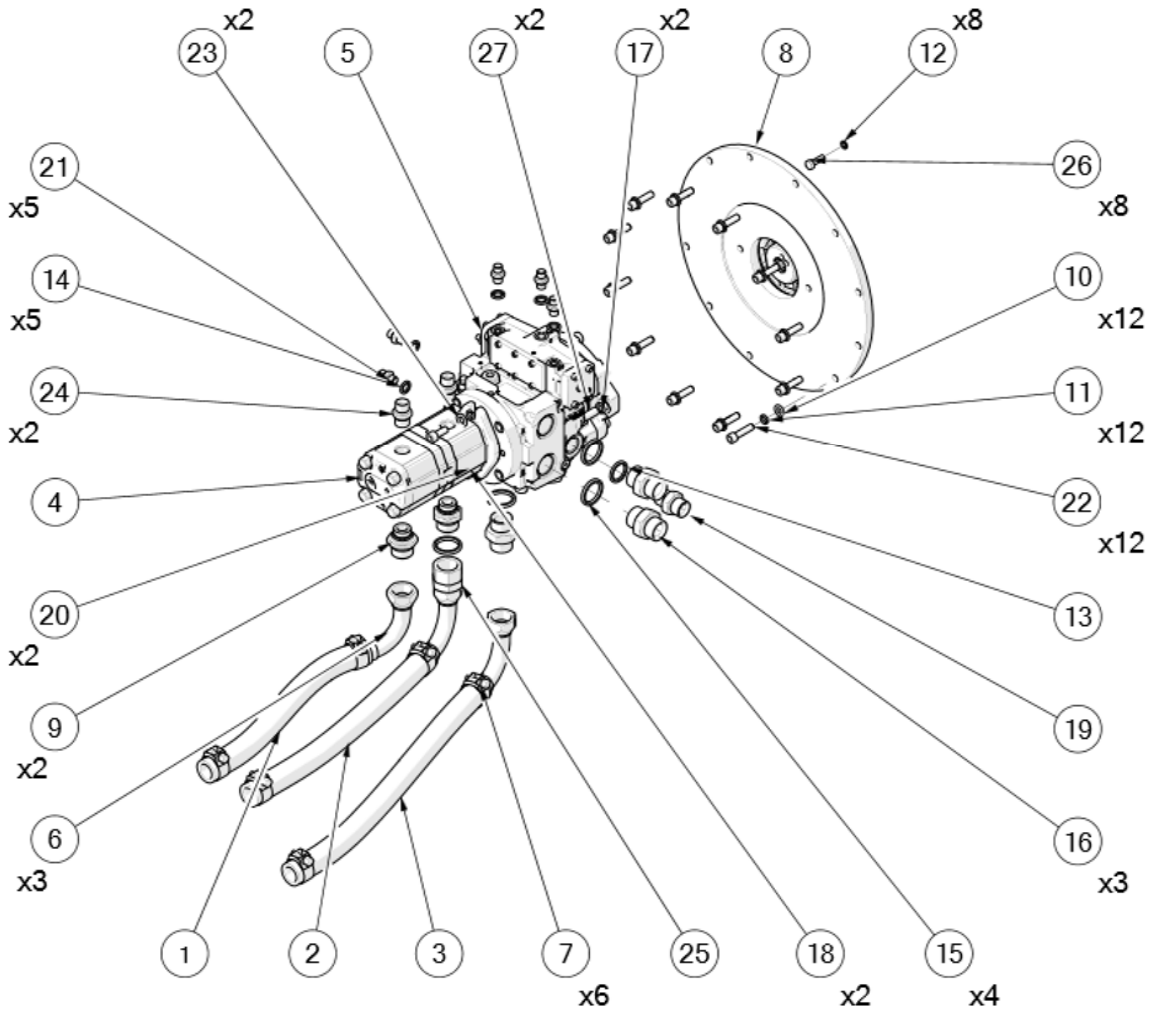
200800297 DANDO DUKE RETURN MANIFOLD ASSEMBLY



200800297 DANDO DUKE RETURN MANIFOLD ASSEMBLY

BOM ID	Number	Description	Qty
1	200800303	HYDRAULIC RETURN MANIFOLD MOUNTING BRACKET [DANDO DUKE]	1
2	200800304	HYDRAULIC RETURN MANIFOLD HOSE GUARD [DANDO DUKE]	1
3	700200186	RETURN MANIFOLD 1in OUTLET [DANDO DUKE]	1
4	700200195	PNEUMATIC POPPET VALVE 0.5in PORT 3 PORT 2 WAY [AIR4U - EM-3241]	1
5	ST00148X328	3/4" NB BONDED SEAL	3
6	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	5
7	ST00246X328	1/2" BSP BONDED SEAL	5
8	ST00300X328	1" BSP BONDED SEAL	1
9	ST00395X326	1" BSP MALE STUD ADAPTOR	1
10	ST01048X881	M10 PLAIN WASHER	6
11	ST01109X510	M10 NYLOC NUT	3
12	ST01152X326	3/4" BSP MALE TO 1/2" BSP MALE STUD ADAPTOR	3
13	ST02061X715	M10 HEX HEAD SET SCREW x 35 LG.	3
14	v2ST04379X510	M8 NYLOC NUT	4
15	ST09754X883	M5 PLAIN WASHER - BRIGHT	4
16	ST09755X510	M5 NYLOC NUT	2
17	ST10440X133	M5 HEX HD BOLT (HT) x 50 LONG	2
18	ST11245X133	M8 HEX HEAD BOLT x 80 LG	4

200800305 HYDRAULIC PUMP ASSEMBLY



8 x TORQUE TIGHTEN
TO 15.3NM

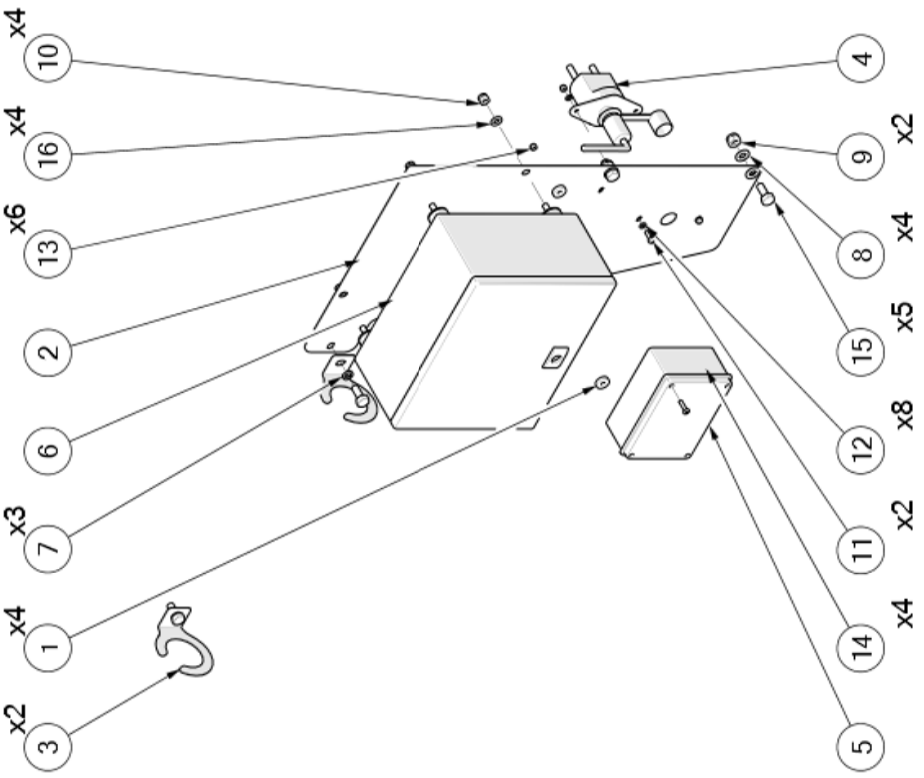
LOCTITE 243 THREADLOCKER
OR EQUIVALENT TO BE ON
22 & 26 UPON ASSY WITH ENGINE

12 x TORQUE TIGHTEN
TO 58.2NM

200800305 HYDRAULIC PUMP ASSEMBLY

BOM ID	Number	Description	Qty
1	200105977	1in ID OIL SUCTION HOSE x 343LG [SAE 100 R4]	1
2	200105978	1in ID OIL SUCTION HOSE x 430LG	1
3	200105979	1in ID OIL SUCTION HOSE x 543LG	1
4	700100107	TANDEM GEAR PUMPS 11ccrev + 8ccrev	1
5	700200187	HYDRAULIC PUMP CLOSED LOOP 35ccrev 300BAR	1
6	700200192	HOSE TAIL 1in ID 1in BSPP [SUITABLE FOR 1in ID HOSE]	3
7	900100219	HOSE CLAMP - MIKALOR SUPRA HD SS W2 03019100 SIZE 37-40	6
8	910100291	ENGINE ADAPTOR KIT DUKE	1
9	C1000056	1" BSP x 1 1/16" UNF MALE/MALE STUD ADAPTOR	2
10	ST00105X880	3/8" NB PLAIN WASHER	12
11	ST00115X884	3/8" N.B. SPRING WASHER	12
12	ST00118X884	5/16" NB SPRING WASHER	8
13	ST00148X328	3/4" NB BONDED SEAL	1
14	ST00298X328	BONDED SEAL 1/4" BSP	5
15	ST00300X328	1" BSP BONDED SEAL	4
16	ST00395X326	1" BSP MALE STUD ADAPTOR	3
17	ST00648X885	M12 SPRING WASHER - SINGLE COIL	2
18	ST00777X885	M10 SINGLE COIL SPRING WASHER	2
19	ST01154X326	3/4" BSP MALE/MALE STUD ADAPTOR	1
20	ST01393X743	M10 SOC HD CAP SCREW x 25 LONG	2
21	ST02282X326	1/4" BSP MALE/MALE STUD ADAPTER	5
22	ST03994X744	3/8"-16 UNC SOCKET HD CAPSCREW x 1 1/2" LONG.	12
23	ST05104X883	M10 PLAIN BRIGHT WASHER	2
24	ST06480X326	1/2" BSP x 7/8" UNF STUD ADAPTOR C/W "O" RING.	2
25	ST09794X326	1" BSP MALE FEMALE EXTENDED STUD ADAPTOR	1
26	ST10035X731	5/16" UNC SET SCREW HEX HD HT x 1" LONG	8
27	ST11143X743	M12 SOCKET HEAD CAPSCREW HT x 40 LONG	2

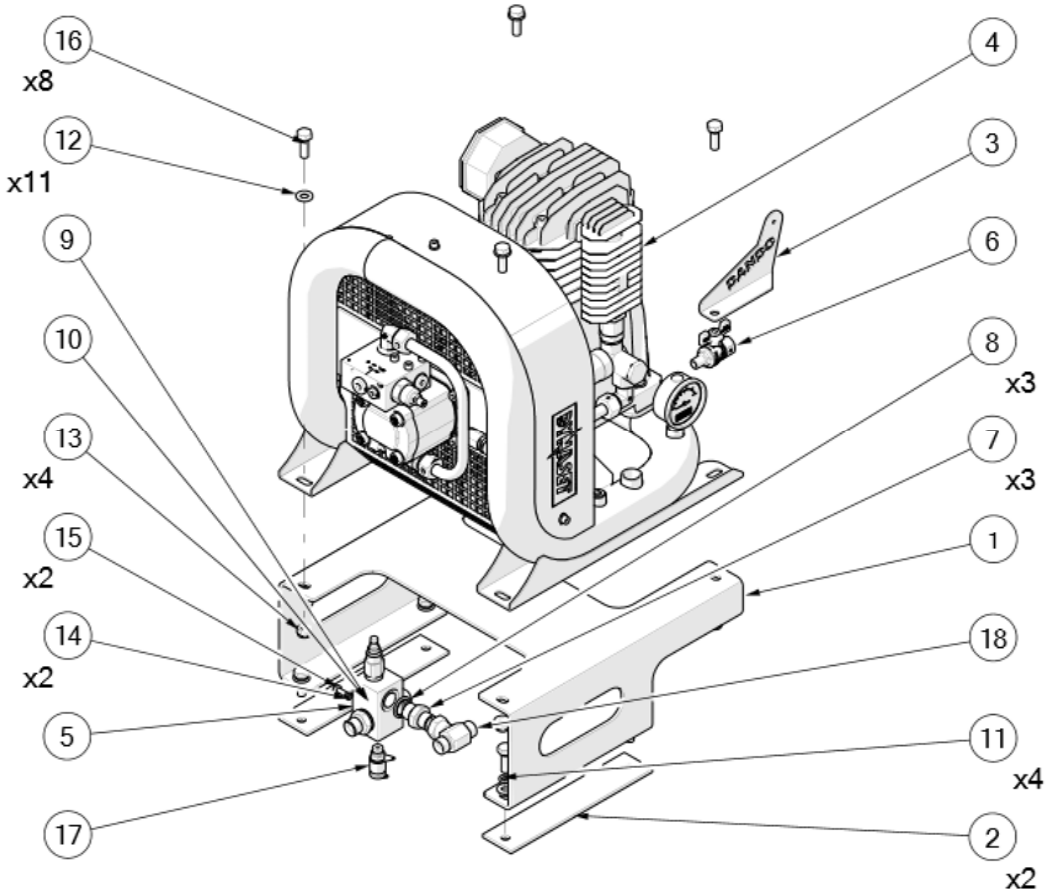
200105501 ELECTRICAL CONTROL ASSEMBLY



200105501 ELECTRICAL CONTROL ASSEMBLY

BOM ID	Number	Description	Qty
1	200101418	JUNCTION BOX RUBBER CUSHION MOUNT	4
2	200105681	ELECTRICAL CONTROL BOX BRACKET	1
3	200105682	CABLE HOOK	2
4	800100145	TIR BATTERY ISOLATOR SWITCH WITH REMOVABLE KEY 250A 24V (RED)	1
5	800100203	JUNCTION BOX IP65 153 X 110 X 66MM	1
6	800105101	CORE ELECTRONICS [DUKE] [CONTROL BOX ONLY]	1
7	ST00777X885	M10 SPRING WASHER	3
8	ST01048X881	M10 PLAIN WASHER	4
9	ST01109X510	M10 NYLOC NUT	2
10	ST04379X510	M8 NYLOC NUT	4
11	ST07458X715	M5 HEX HEAD SET SCREW x 15 LONG	2
12	ST09754X883	M5 PLAIN WASHER (BRIGHT)	8
13	ST09755X510	M5 NYLOC NUT	6
14	ST10131X788	M5 SCREW PAN HEAD RECESSED x 20 LONG	4
15	ST10142X133	M10 HEX HD BOLT HT x 25 LONG	5
16	ST10249X883	M8 PLAIN BRIGHT WASHER	4

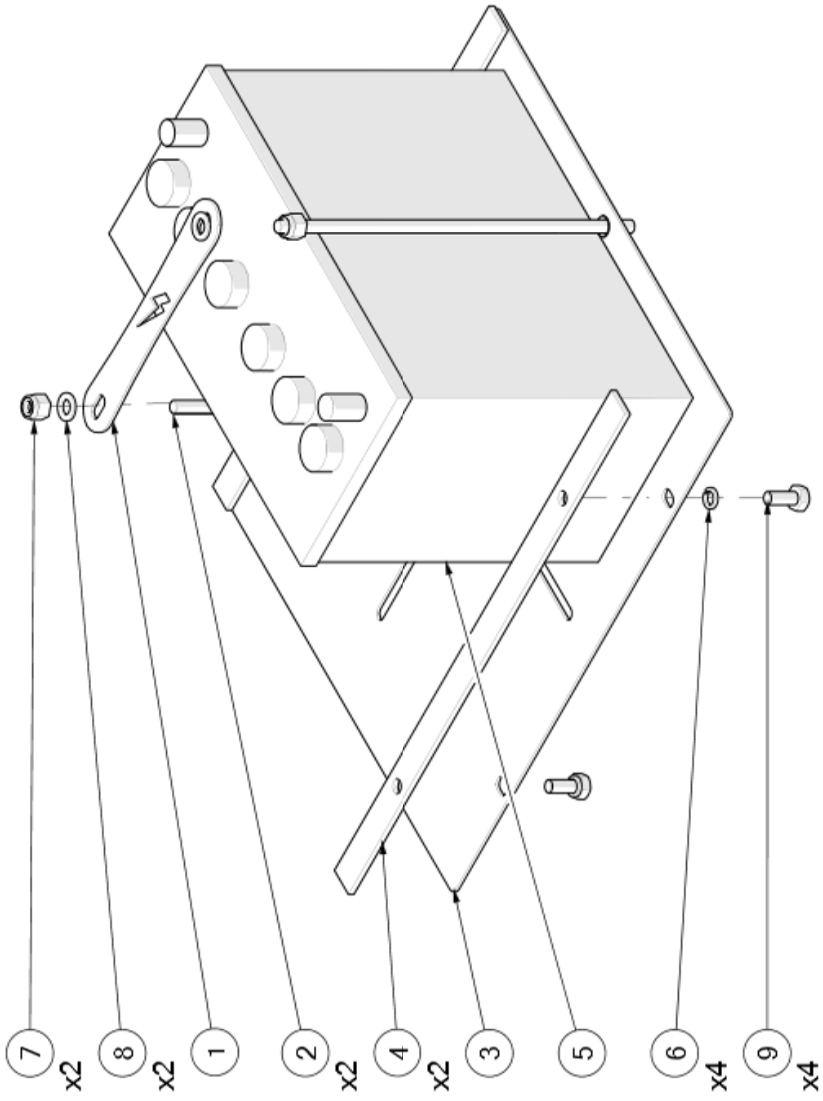
200800237 COMPRESSOR MODULE



200800237 COMPRESSOR MODULE

BOM ID	Number	Description	Qty
1	200105602	COMPRESSOR BRACKET	1
2	200105603	COMPRESSOR RUBBER MOUNT	2
3	200108375	HOSE SUPPORT - COMPRESSOR NON-RETURN	1
4	700100101	AIR COMPRESSOR UNIT HYDRAULICALLY DRIVEN	1
5	700200282	DIRECT ACTING PRESSURE RELIEF VALVE 0.5IN PORT 35-210BAR	1
6	910100370	FULL FLOW T-HANDLE - 1/4" BSPT MALE X 1/4" BSPP FEMALE - 10 BAR [B/V2379-04]	1
7	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	3
8	ST00246X328	1/2" BSP BONDED SEAL	3
9	ST00298X328	BONDED SEAL 1/4" BSP	1
10	ST00728X338	1/4" BSP HEX HEAD PLUG	1
11	ST00777X885	M10 SINGLE COIL SPRING WASHER	4
12	ST01048X881	M10 PLAIN WASHER	11
13	ST01109X510	M10 NYLOC NUT	4
14	ST01179X885	M6 SPRING WASHER	2
15	ST02259X715	M6 SET SCREW X 15 LG	2
16	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	8
17	ST09970X850	0.25in BSP x M16 TEST POINT	1
18	ST11572X355	1/2" BSPP MALE x BSPP MALE x BSPP SWIVEL FEMALE BRANCH TEE	1

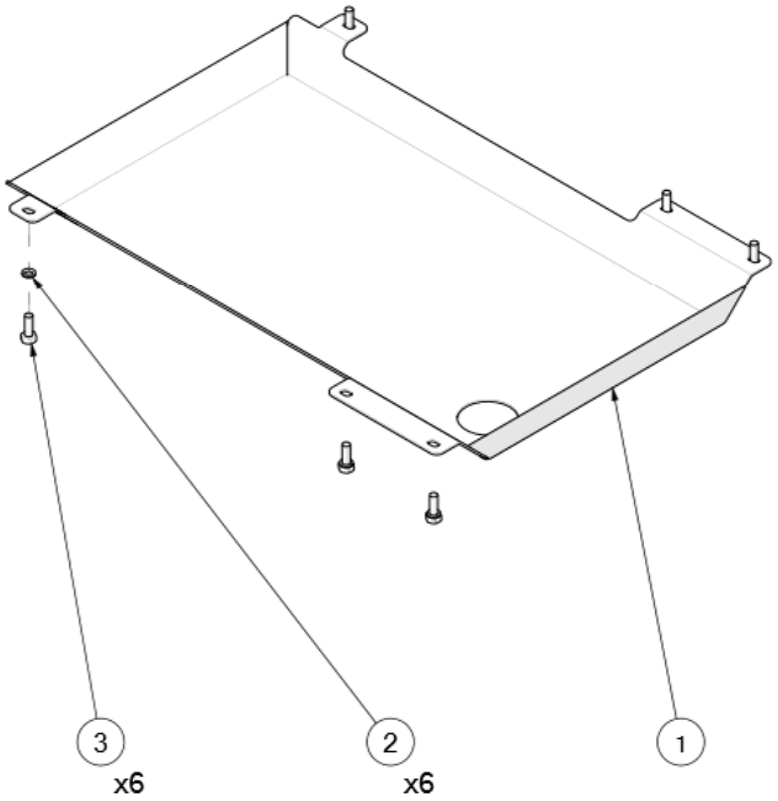
200105510 BATTERY ASSEMBLY



200105510 BATTERY ASSEMBLY

BOM ID	Number	Description	Qty
1	200101421	BATTERY CLAMP	1
2	200101424	M10 STUDDING x 320 LONG	2
3	200105507	BATTERY BASE FABRICATION	1
4	200105509	BATTERY BASE RUBBER CUSHION MOUNT	2
5	800100175	12V NUMAX 655 COMMERCIAL BATTERY	1
6	ST00777X885	M10 SINGLE COIL SPRING WASHER	4
7	ST01109X510	M10 NYLOC NUT	2
8	ST05104X883	M10 PLAIN BRIGHT WASHER	2
9	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	4

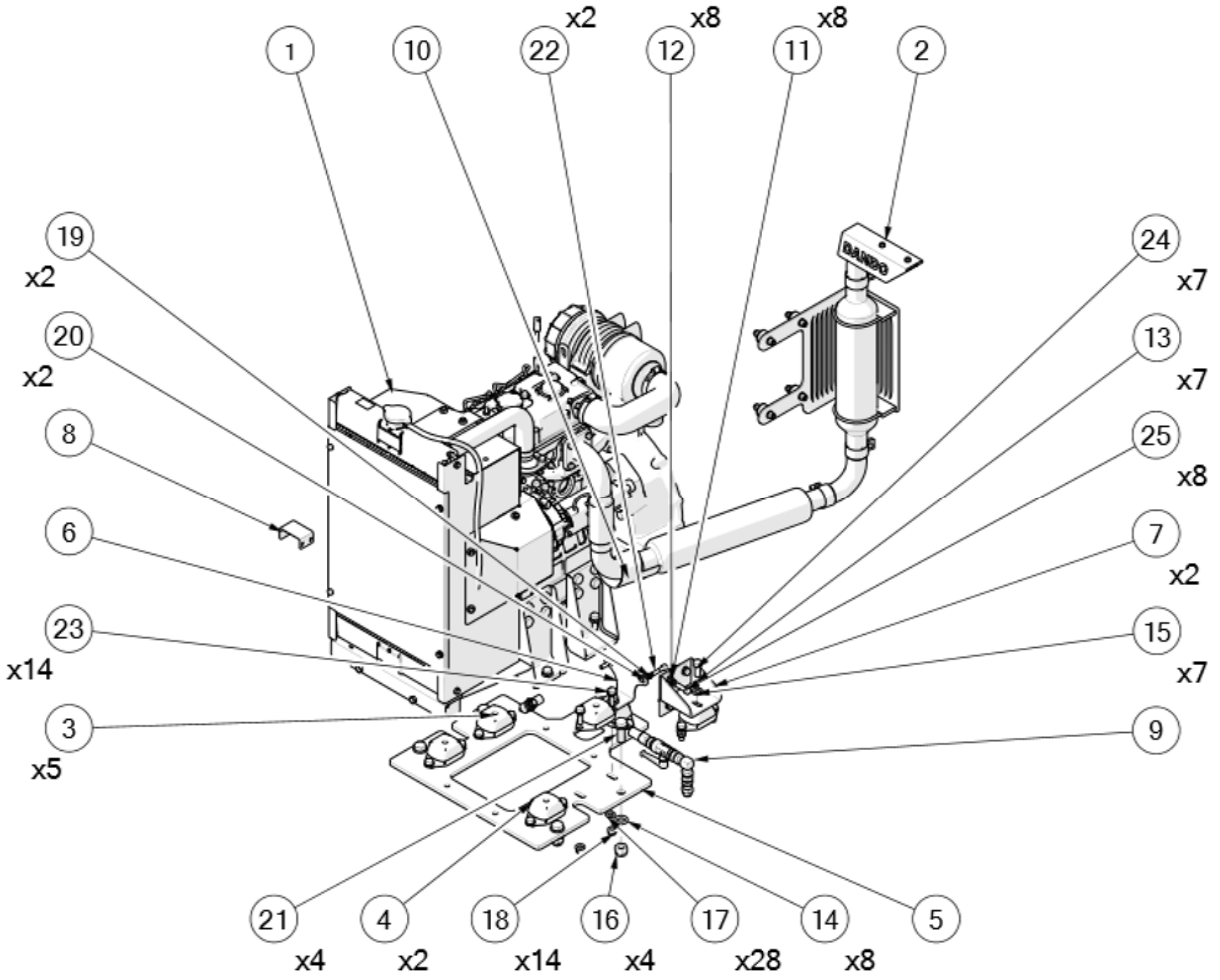
200105355 GUARD ASSEMBLY (HYD OIL TANK)



200105355 GUARD ASSEMBLY (HYD OIL TANK)

BOM ID	Number	Description	Qty
1	200105356	GUARD (HYD. OIL TANK)	1
2	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	6
3	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	6

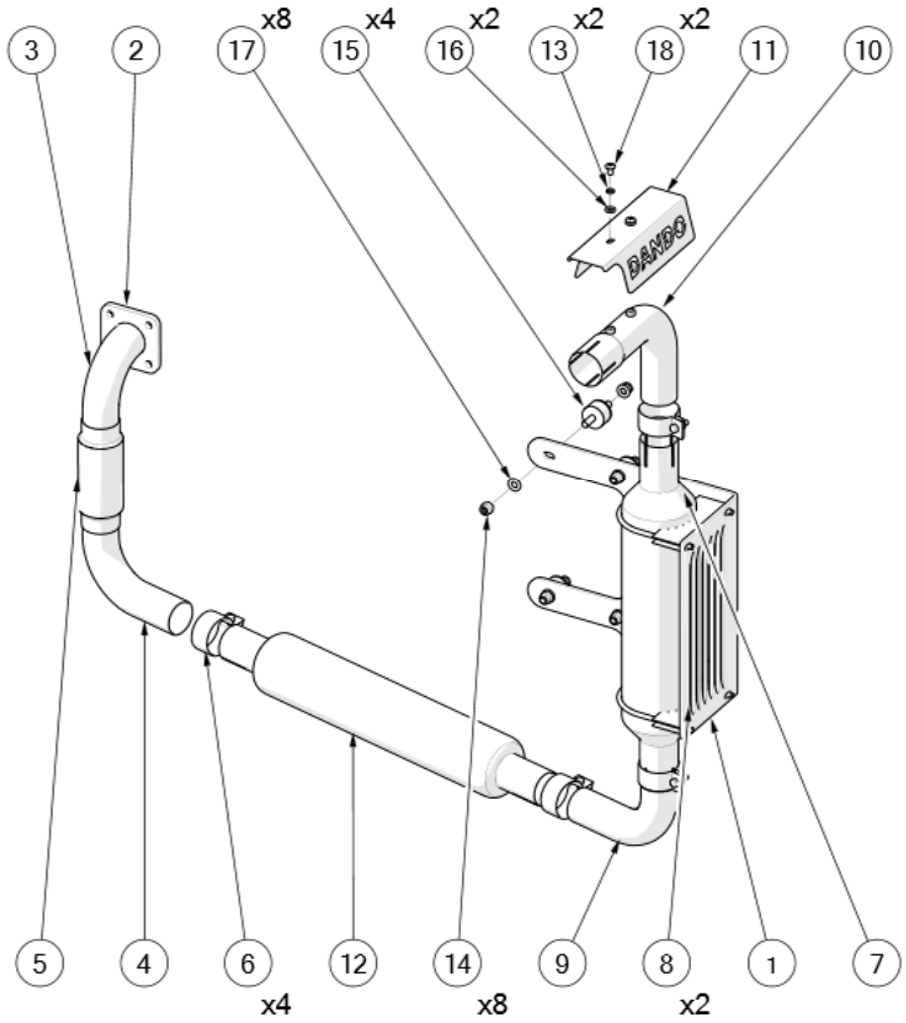
200105152 ENGINE ASSEMBLY



200105152 ENGINE ASSEMBLY

BOM ID	Number	Description	Qty
1	200100701	PERKINS 403D-15 IOPU ENGINE	1
2	200100925	DUKE EXHAUST MK2 ASSEMBLY	1
3	200101514	ANTI VIBRATION FOOT (CCFQ804012H)	5
4	200101515	ANTI VIBRATION FOOT (CCFQ804012W)	2
5	200105151	ENGINE MOUNTING PLATE	1
6	200105551	ENGINE ADAPTOR MOUNT	1
7	200107777	ENGINE MOUNT FAB	2
8	200107778	FUEL FILTER MOUNT	1
9	200800504	ENGINE OIL DRAIN EXTENSION ASSY	1
10	C100G01657	EXHAUST HEAT WRAP 50mm X 30m	1
11	ST00105X880	3/8" NB PLAIN WASHER	8
12	ST00115X884	3/8" NOM BORE SPRING WASHER SINGLE COIL	8
13	ST00648X885	M12 SPRING WASHER - SINGLE COIL	7
14	ST00656X881	M16 ORDINARY WASHER	8
15	ST00788X881	M12 PLAIN WASHER	7
16	ST00934X510	M16 NYLOC NUT	4
17	ST01048X881	M10 PLAIN WASHER	28
18	ST01109X510	M10 NYLOC NUT	14
19	ST01146X885	M8 SPRING WASHER SINGLE COIL	2
20	ST01176X881	M8 PLAIN WASHER	2
21	ST02957X133	M16 HEX HEAD BOLT HT x 45 LG.	4
22	ST04349X743	ST04349X743 {NON-STUD} m8 soc cap screw x 40.SLDPRT	2
23	ST04534X133	M10 HEX HEAD BOLT x 35 LONG	14
24	ST07889X133	M12 HEX HEAD BOLT HT X 30 LONG	7
25	ST12726X731	3/8" UNC HEX HEAD SET SCREW HT x 1 1/4" LG	8

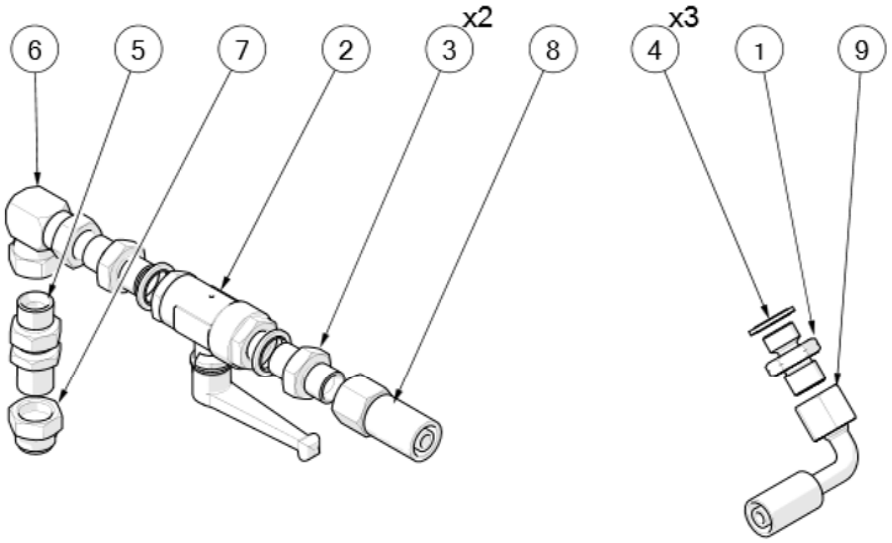
200100925 DUKE EXHAUST MK2 ASSEMBLY



200100925 DUKE EXHAUST MK2 ASSEMBLY

BOM ID	Number	Description	Qty
1	200100924	EXHAUST MOUNTING BRACKET	1
2	200101348	MANIFOLD FLANGE MODS	1
3	200101349	EXHAUST BEND MODS - 75 x 80	1
4	200101350	EXHAUST BEND MODS - 80 x 180	1
5	200101353	EXHAUST FLEXIBLE - STAINLESS STEEL Iloc 44.45 [1.75"] ID x 150LG	1
6	200101354	48.5 DIA (1 7/8") EXHAUST CLAMP	4
7	200101355	SPARK ARRESTOR/SILENCER	1
8	200101356	U-BOLT [CLAMP] 92 O.D. DINEX 90092	2
9	200101357	EXHAUST BEND 90 DEG 45 OD/OD	1
10	200115332	EXHAUST BEND - C/W FIXINGS	1
11	200115336	HEAT SHIELD	1
12	900100138	1.75 MICRO 45 STAINLESS STEEL ROUND SILENCER BOX	1
13	ST01179X885	M6 SPRING WASHER	2
14	ST04379X510	M8 NYLOC NUT	8
15	ST09902X478	SHOCK ABSORBER - BUFFER TYPE A 30/20-M8 x 20 NR 57 SHORE A	4
16	ST09948X883	M6 ORDINARY WASHER - BRIGHT	2
17	ST10249X883	M8 PLAIN BRIGHT WASHER	8
18	ST11763X788	M6 SCREW PAN HEAD RECESSED x 10 LONG	2

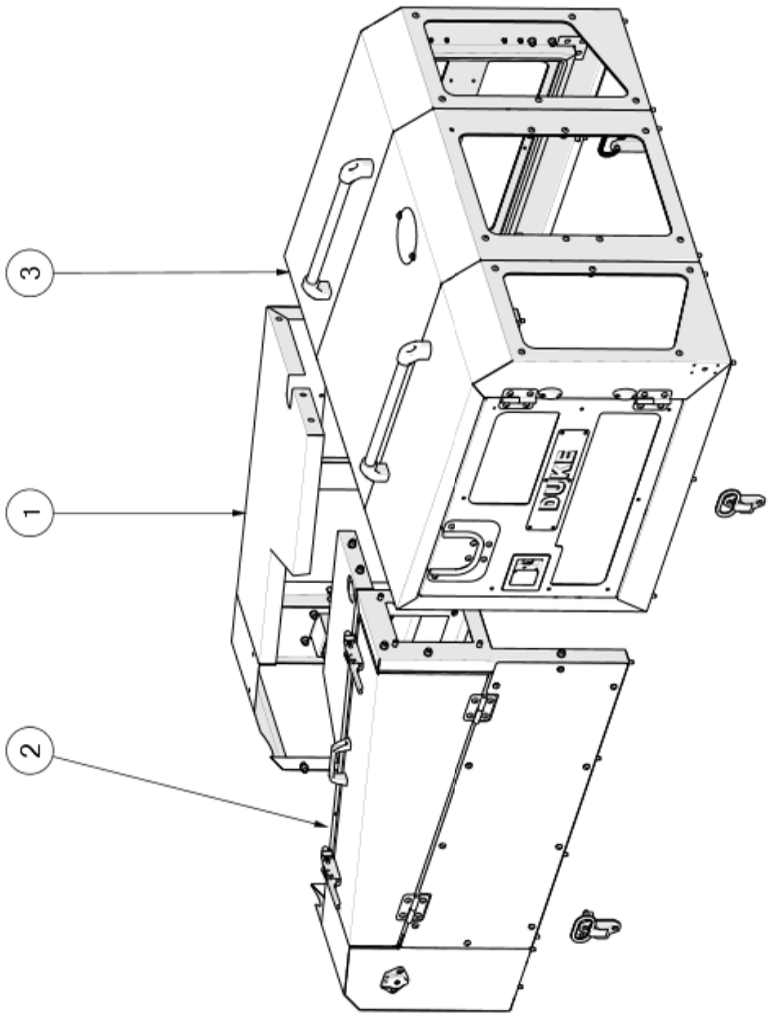
200800504 ENGINE OIL DRAIN EXTENSION ASSEMBLY



200800504 ENGINE OIL DRAIN EXTENSION ASSEMBLY

BOM ID	Number	Description	Qty
1	700200299	STUD ADAPTOR M16 X 1.5 X 0.375BSP M-M	1
2	C115C0053	3/8" BSPP FEMALE BRASS LEVER OPERATED BALL VALVE	1
3	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	2
4	ST01156X328	3/8"BSP BONDED SEAL	3
5	ST08827X315	3/8" BSP MALE/MALE [60° CONE] BULKHEAD C/W LOCK NUT	1
6	ST10049X329	90 COMPACT ELBOW 3/8"BSP F/F	1
7	ST10937X322	3/8" BSPP BLANKING CAP (SWIVEL)	1
8	ST20107X331	3/8" BSPP STRAIGHT FEMALE SWIVEL SWAGED HOSE END	1
9	ST20108X332	3/8" BSP 90 DEG. FEMALE SWEPT HOSE END	1

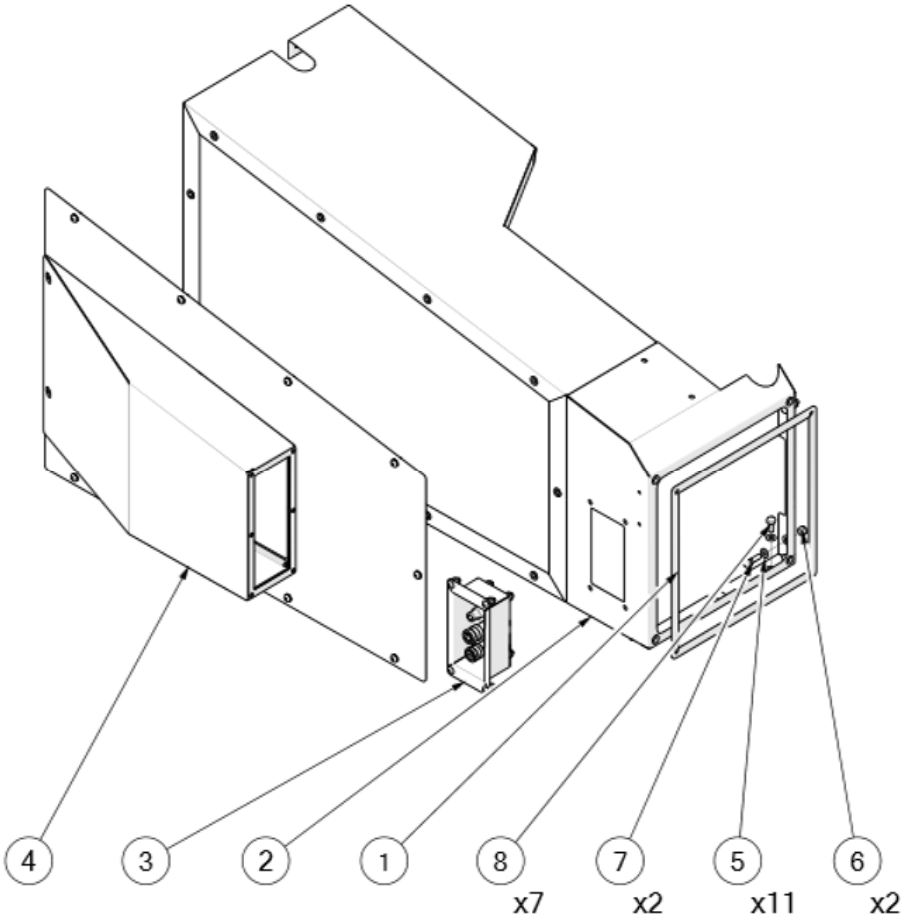
200105457 CANOPY ASSEMBLY



200105457 CANOPY ASSEMBLY

BOM ID	Number	Description	Qty
1	200105411	FRONT CANOPY ASSEMBLY [OS]	1
2	200105412	FRONT CANOPY ASSEMBLY [NS]	1
3	200105415	REAR CANOPY ASSEMBLY	1

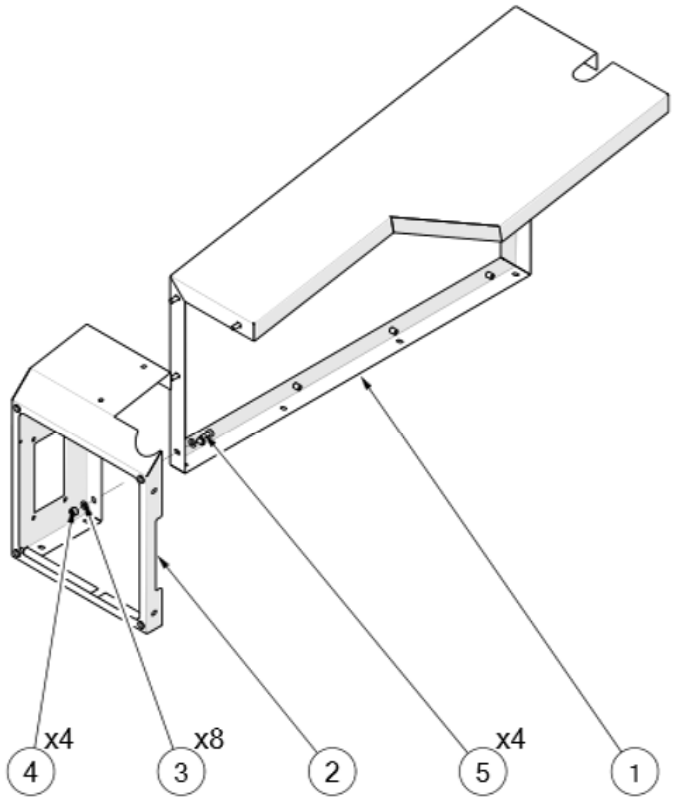
200105411 FRONT CANOPY ASSEMBLY [OS]



200105411 FRONT CANOPY ASSEMBLY [OS]

BOM ID	Number	Description	Qty
1	200100968	FRONT CANOPY ANTI RATTLE MESH RUBBER	1
2	200105408	FRONT CANOPY SUB-ASSEMBLY [OS]	1
3	200105449	1/2" BSP HYD QUICK CONNECT ASSY	1
4	200105663	FRONT CANOPY DOOR AND PANEL ASSEMBLY [OS] (POCLAIN CW SPLINED SHAFT)	1
5	ST01048X881	M10 PLAIN WASHER	11
6	ST01109X510	M10 NYLOC NUT	2
7	ST04534X133	M10 HEX HEAD BOLT x 35 LONG	2
8	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	7

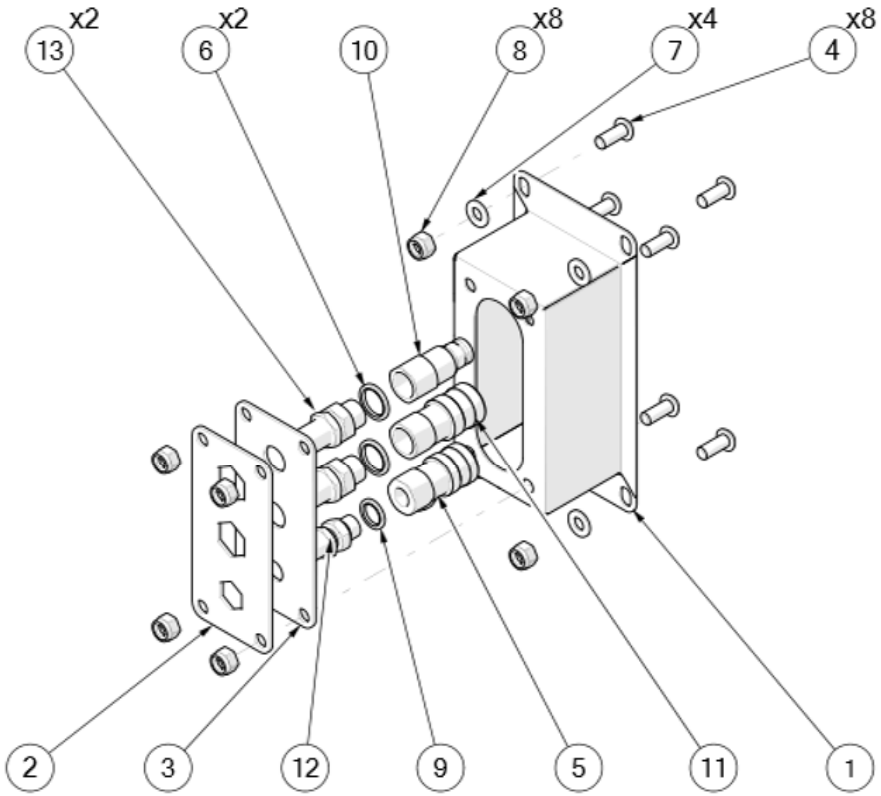
200105408 FRONT CANOPY SUB-ASSEMBLY [OS]



200105408 FRONT CANOPY SUB-ASSEMBLY [OS]

BOM ID	Number	Description	Qty
1	200105300	FRONT CANOPY FRAME FABRICATION	1
2	200105407	FRONT CANOPY OS	1
3	ST01048X881	M10 PLAIN WASHER	8
4	ST01109X510	M10 NYLOC NUT	4
5	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	4

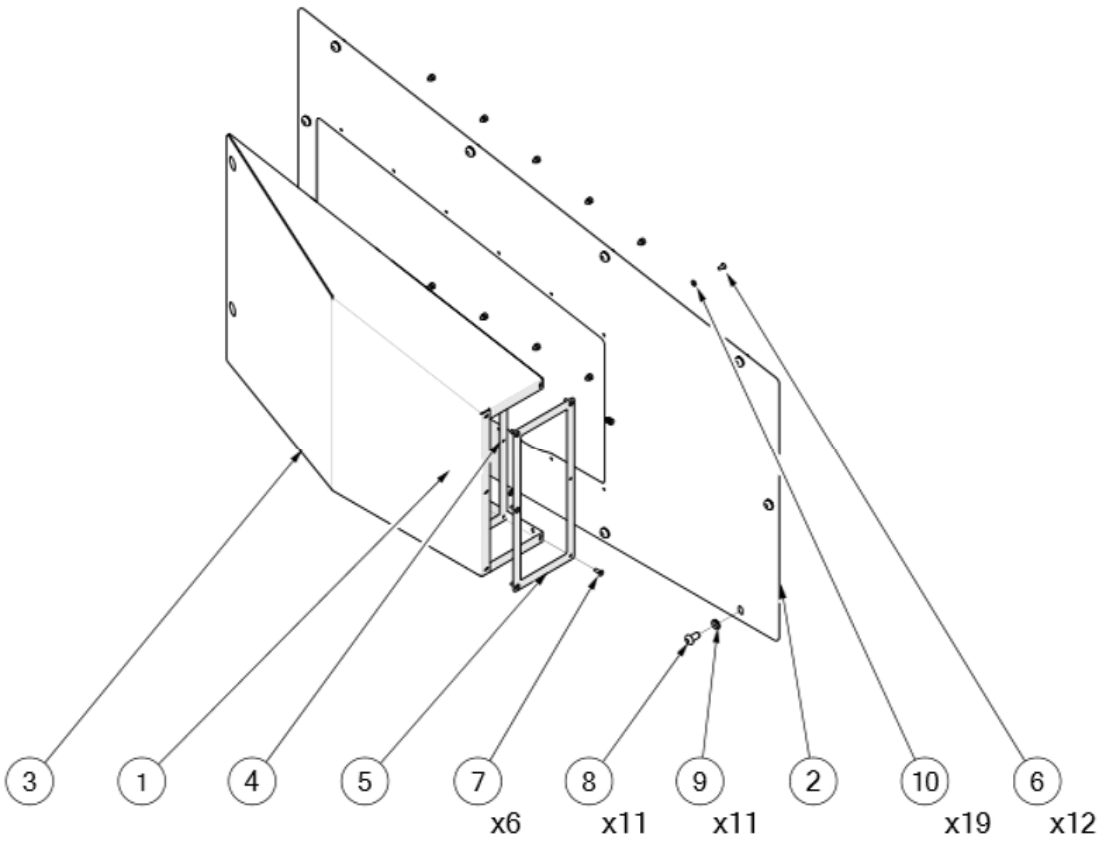
200105449 1/2" BSP HYDRAULIC QUICK CONNECT ASSEMBLY



200105449 1/2" BSP HYDRAULIC QUICK CONNECT ASSEMBLY

BOM ID	Number	Description	Qty
1	C002C0131094	QUICK CONNECT HOUSING [MT4000 MK3]	1
2	C002C0131095	BULK HEAD LOCK PLATE 0.5IN BSP [QUICK CONNECT MT4000 MK3]	1
3	C002C0131101	BULK HEAD PLATE 0.5IN BSP [QUICK CONNECT MT4000 MK3]	1
4	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	8
5	C102G0053	3/8" BSP FEMALE FLAT FACE SNAP COUPLING	1
6	ST00246X328	1/2" BSP BONDED SEAL	2
7	ST01048X881	M10 PLAIN WASHER	4
8	ST01109X510	M10 NYLOC NUT	8
9	ST01156X328	3/8"BSP BONDED SEAL	1
10	ST01875X168	1/2" BSP MALE SNAP COUPLING	1
11	ST01876X168	1/2" BSP FEMALE SNAP COUPLING	1
12	ST08827X315	3/8" BSP MALE/MALE [60° CONE] BULKHEAD C/W LOCK NUT	1
13	ST08967X315	1/2"BSP BULKHEAD COMPLETE WITH LOCK NUT	2

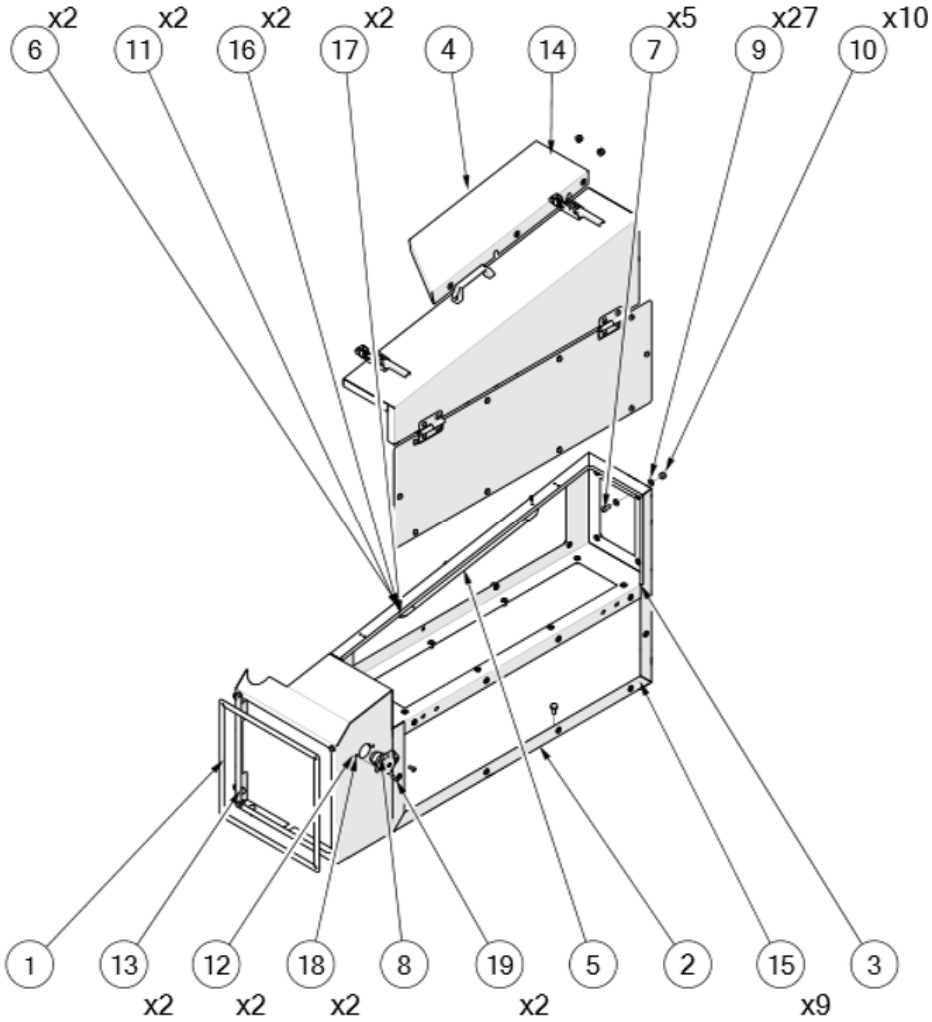
200105663 FRONT CANOPY DOOR AND PANEL ASSEMBLY [OS]



200105663 FRONT CANOPY DOOR AND PANEL ASSEMBLY [OS]

BOM ID	Number	Description	Qty
1	200100967	MOTOR COVER MESH BACKING PLATE (POCLAIN CW SPLINED SHAFT) ANTI RATTLE MESH RUBBER	1
2	200105306	COVER PLATE (HOISTING REEL ASSY)	1
3	200105664	MOTOR COVER (POCLAIN CW SPLINED SHAFT)	1
4	200105665	MOTOR HOUSING MESH (POCLAIN CW SPLINED SHAFT)	1
5	200105666	MOTOR COVER MESH BACKING PLATE (POCLAIN CW SPLINED SHAFT)	1
6	900100127	4.8MM DIA S.S. POP RIVET 10.8MM	12
7	900100128	4.8MM DIA S.S. POP RIVET 14MM	6
8	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	11
9	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	11
10	ST09754X883	M5 PLAIN WASHER - BRIGHT	19

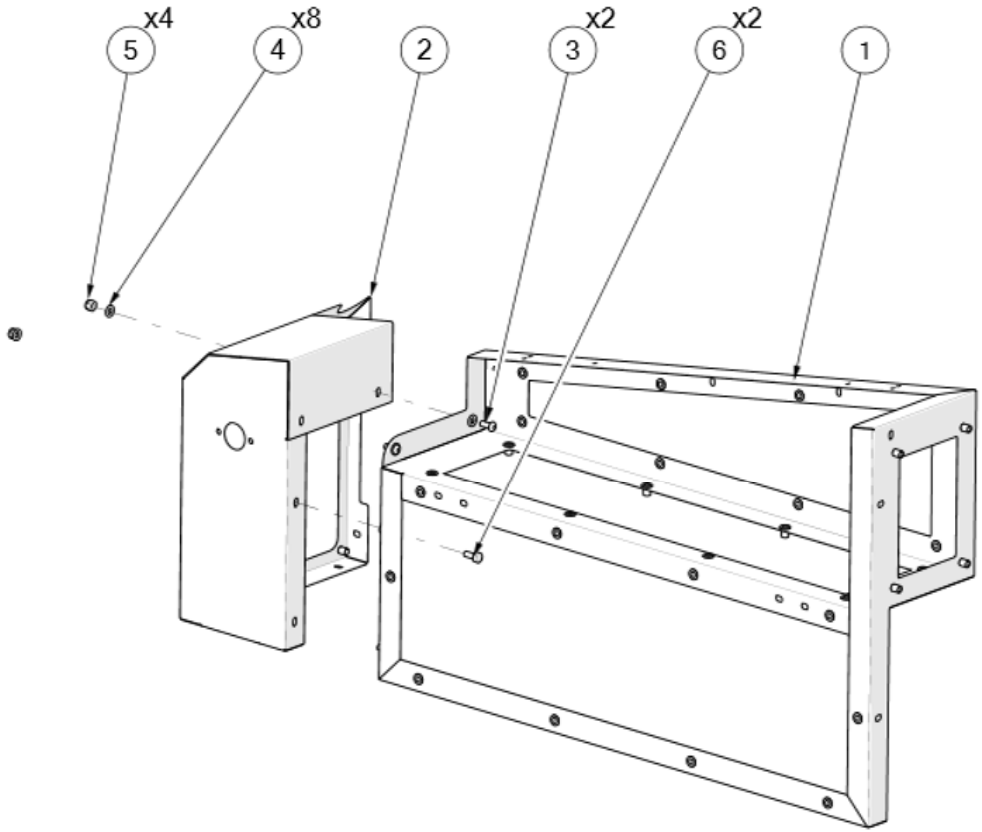
200105412 FRONT CANOPY ASSEMBLY [NS]



200105412 FRONT CANOPY ASSEMBLY [NS]

BOM ID	Number	Description	Qty
1	200100968	FRONT CANOPY ANTI RATTLE MESH RUBBER	1
2	200105907	FRONT CANOPY SUB-ASSEMBLY [NS]	1
3	200105913	EDGE TRIM [1700 LG]	1
4	200105914	FRONT CANOPY [NS] DOOR AND PANEL ASSEMBLY	1
5	800100200	NEBULA 12V SWITCHED STRIP LIGHT 500MM	1
6	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	2
7	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	5
8	C102C0085	PLUG TRAILER HEAVY DUTY 3 PIN 12V	1
9	ST01048X881	M10 PLAIN WASHER	27
10	ST01109X510	M10 NYLOC NUT	10
11	ST04149X885	M5 SPRING WASHER	2
12	ST04379X510	M8 NYLOC NUT	2
13	ST04534X133	M10 HEX HEAD BOLT x 35 LONG	2
14	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	1
15	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	9
16	ST09754X883	M5 PLAIN WASHER (BRIGHT)	2
17	ST09755X510	M5 NYLOC NUT	2
18	ST10249X883	M8 PLAIN BRIGHT WASHER	2
19	ST10810X792	M8 SOCKET BUTTON HEAD SCREW x 20 LONG	2

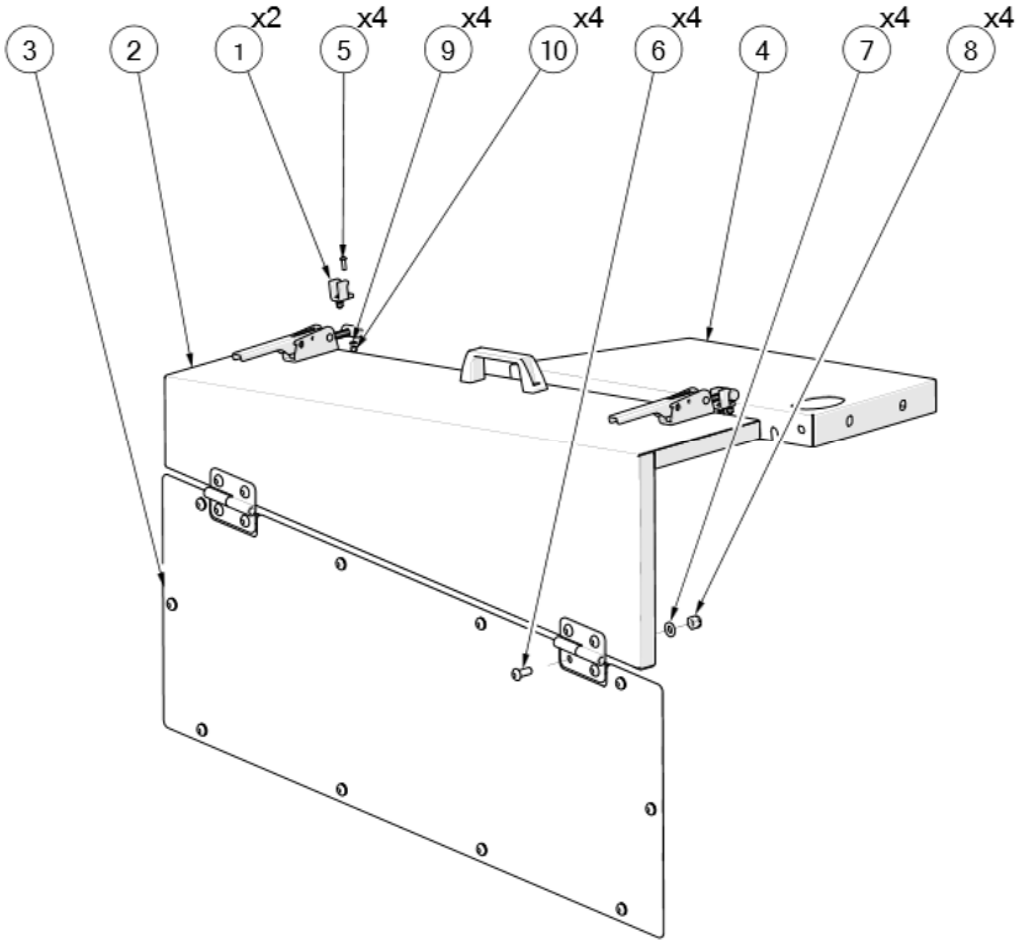
200105907 FRONT CANOPY SUB-ASSEMBLY [NS]



200105907 FRONT CANOPY SUB-ASSEMBLY [NS]

BOM ID	Number	Description	Qty
1	200105908	CONTROL CONSOLE FRAME FABRICATION	1
2	200105909	FRONT CANOPY NS	1
3	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	2
4	ST01048X881	M10 PLAIN WASHER	8
5	ST01109X510	M10 NYLOC NUT	4
6	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	2

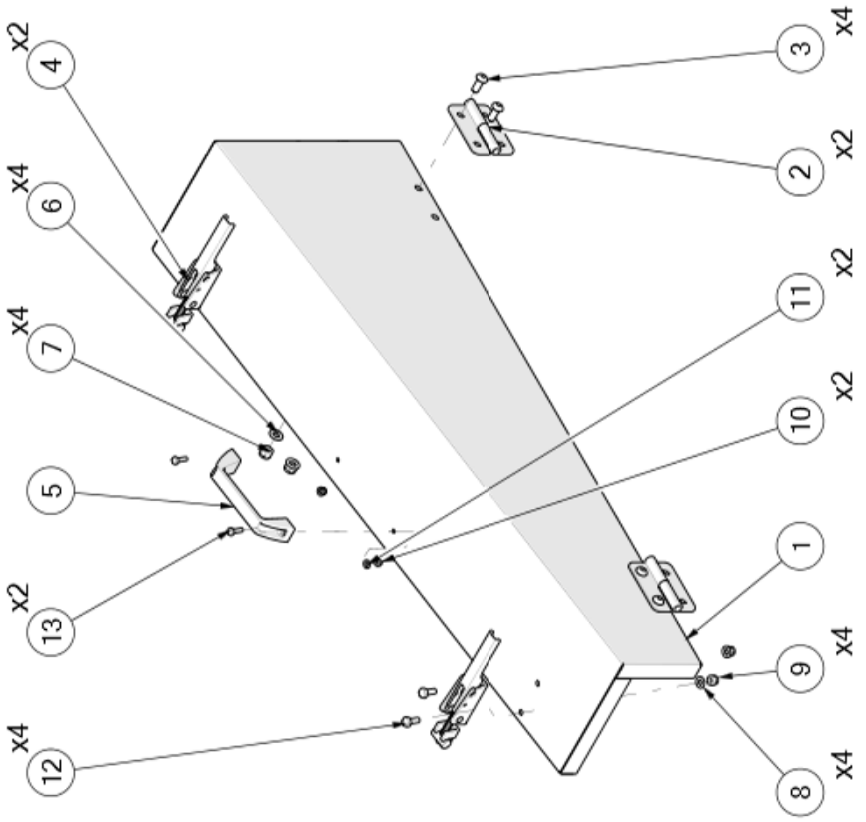
200105914 FRONT CANOPY [NS] DOOR AND PANEL ASSEMBLY



200105914 FRONT CANOPY [NS] DOOR AND PANEL ASSEMBLY

BOM ID	Number	Description	Qty
1	200105901	MODS TO CATCH PLATE	2
2	200105917	FRONT CANOPY [NS] DOOR ASSEMBLY	1
3	200105919	FRONT CANOPY DOOR AND PANEL ASSEMBLY [NS]	1
4	200105976	TOP PANEL O/S FABRICATION	1
5	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	4
6	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	4
7	ST01048X881	M10 PLAIN WASHER	4
8	ST01109X510	M10 NYLOC NUT	4
9	ST09754X883	M5 PLAIN WASHER (BRIGHT)	4
10	ST09755X510	M5 NYLOC NUT	4

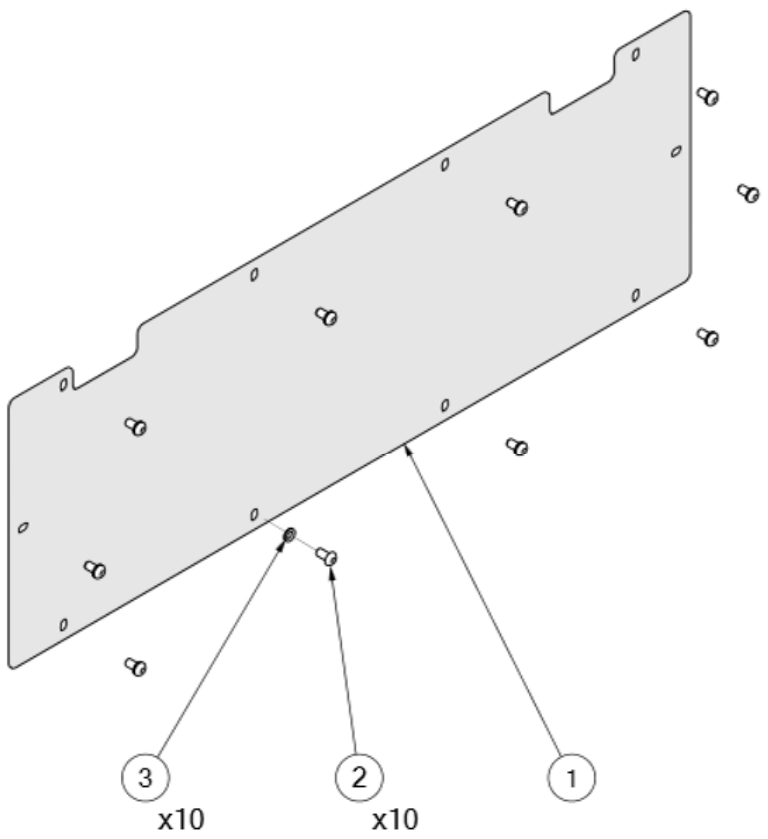
200105917 FRONT CANOPY [NS] DOOR ASSEMBLY



200105917 FRONT CANOPY [NS] DOOR ASSEMBLY

BOM ID	Number	Description	Qty
1	200105915	COVER FABRICATION (CONTROL CONSOLE)	1
2	C10001135	LIFT OFF HINGE - R/H	2
3	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	4
4	C102C01616	TOGGLE LATCH - HEAVY DUTY PADLOCKABLE	2
5	C117M01624	BLACK NYLON HANDLE	1
6	ST01048X881	M10 PLAIN WASHER	4
7	ST01109X510	M10 NYLOC NUT	4
8	ST01176X881	M8 PLAIN WASHER	4
9	ST04379X510	M8 NYLOC NUT	4
10	ST04435X510	M6 NYLOC NUT	2
11	ST09948X883	M6 ORDINARY WASHER - BRIGHT	2
12	ST11946X133	M8 HEX HEAD BOLT (HT) x 20 LONG	4
13	ST12607X715	M6 HEX HEAD SET SCREW HT x 20 LONG.	2

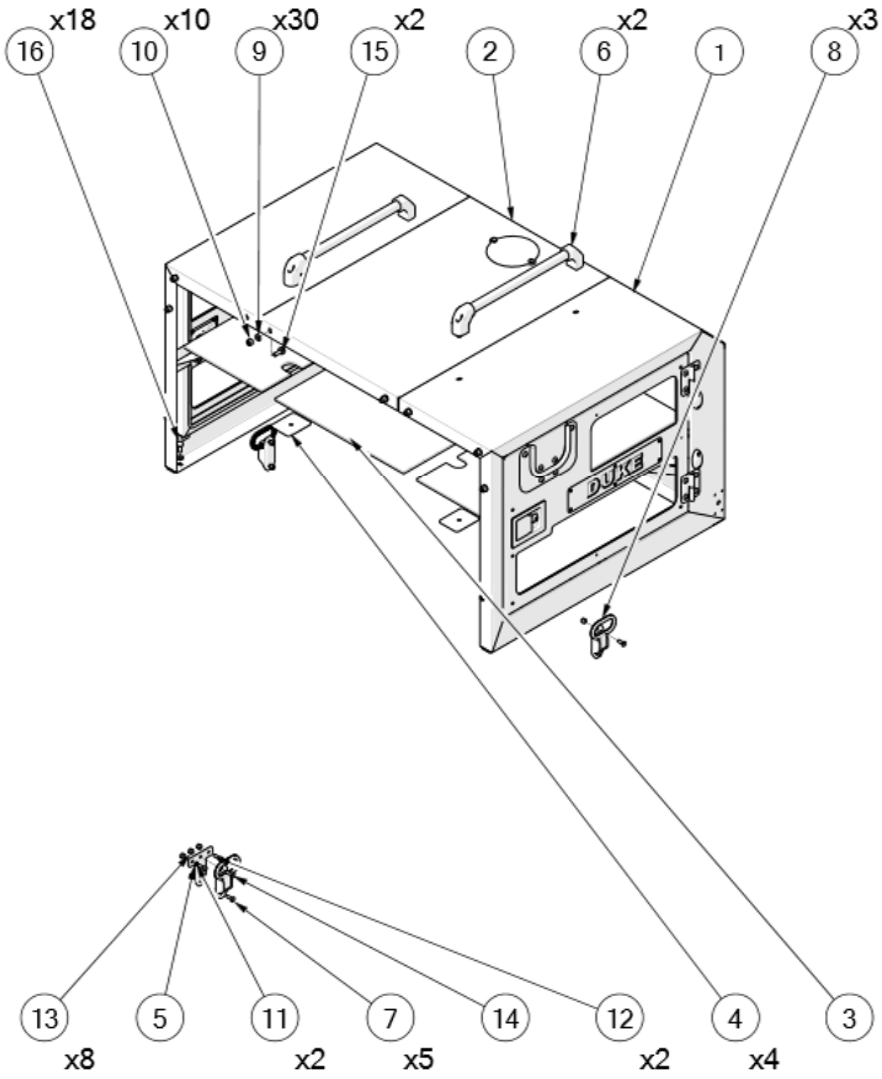
200105919 FRONT CANOPY DOOR AND PANEL ASSEMBLY [NS]



200105919 FRONT CANOPY DOOR AND PANEL ASSEMBLY [NS]

BOM ID	Number	Description	Qty
1	200105918	CONTROL CONSOLE FRONT COVER	1
2	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	10
3	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	10

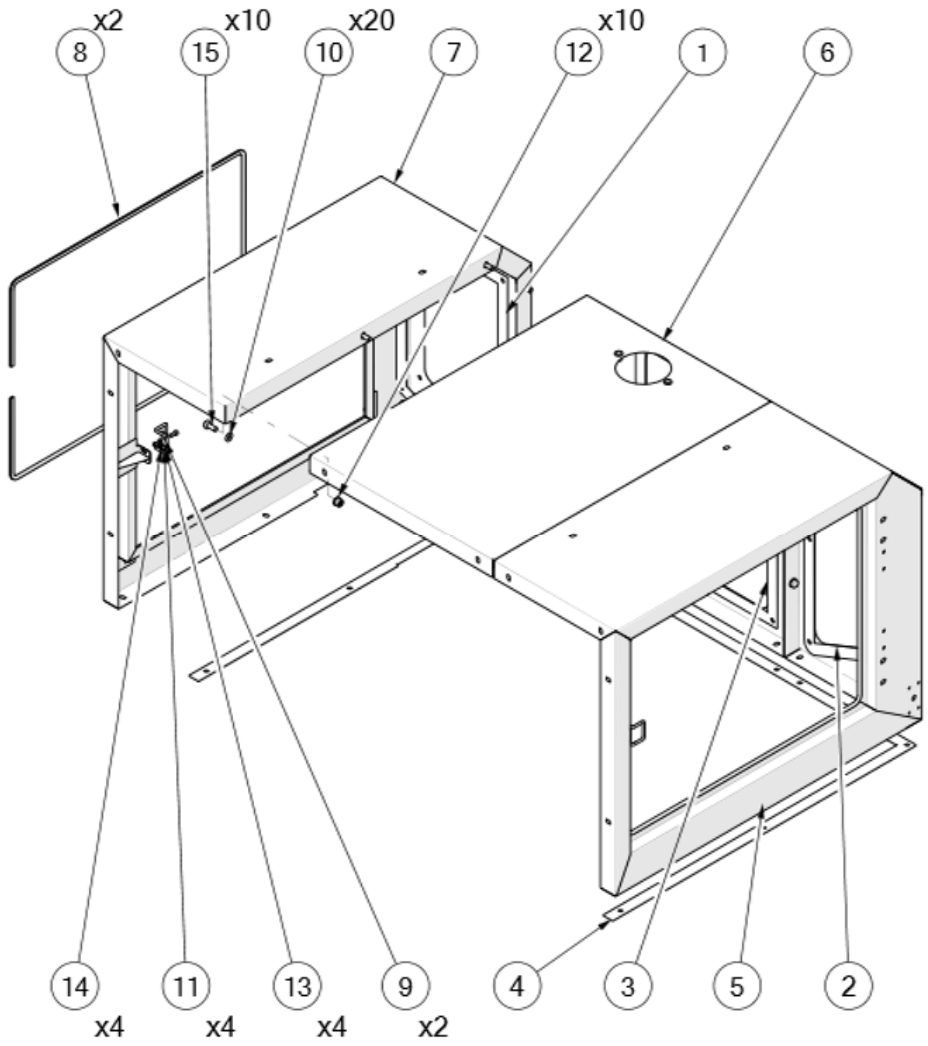
200105415 REAR CANOPY ASSEMBLY



200105415 REAR CANOPY ASSEMBLY

BOM ID	Number	Description	Qty
1	200105414	REAR CANOPY SUB-ASSEMBLY	1
2	200105416	REAR CANOPY DOOR AND PANEL ASSEMBLY	1
3	200105571	DUKE ENGINE THERMAL ACOUSTIC SOUND DEADENING LINING	1
4	200108370	SPECIAL WASHER - HANDRAIL MOUNT	4
5	200800503	FOLDING STEP MOUNT	1
6	900100245	TUBED HANDLE WITH STAINLESS STEEL GRIP (WDS 8517-607)	2
7	C10001134	M8 SOCKET HEAD COUNTERSUNK SCREW x 25 LONG	5
8	C102C01620	FOLDING STEP STAINLESS	3
9	ST01048X881	M10 PLAIN WASHER	30
10	ST01109X510	M10 NYLOC NUT	10
11	ST01146X885	M8 SPRING WASHER SINGLE COIL	2
12	ST01813X743	M8 SOCKET HEAD CAPSCREW x 25 LONG	2
13	v2ST04379X510	M8 NYLOC NUT	8
14	ST04882X763	M8 SOC CSK SCREW x 30	1
15	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	2
16	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	18

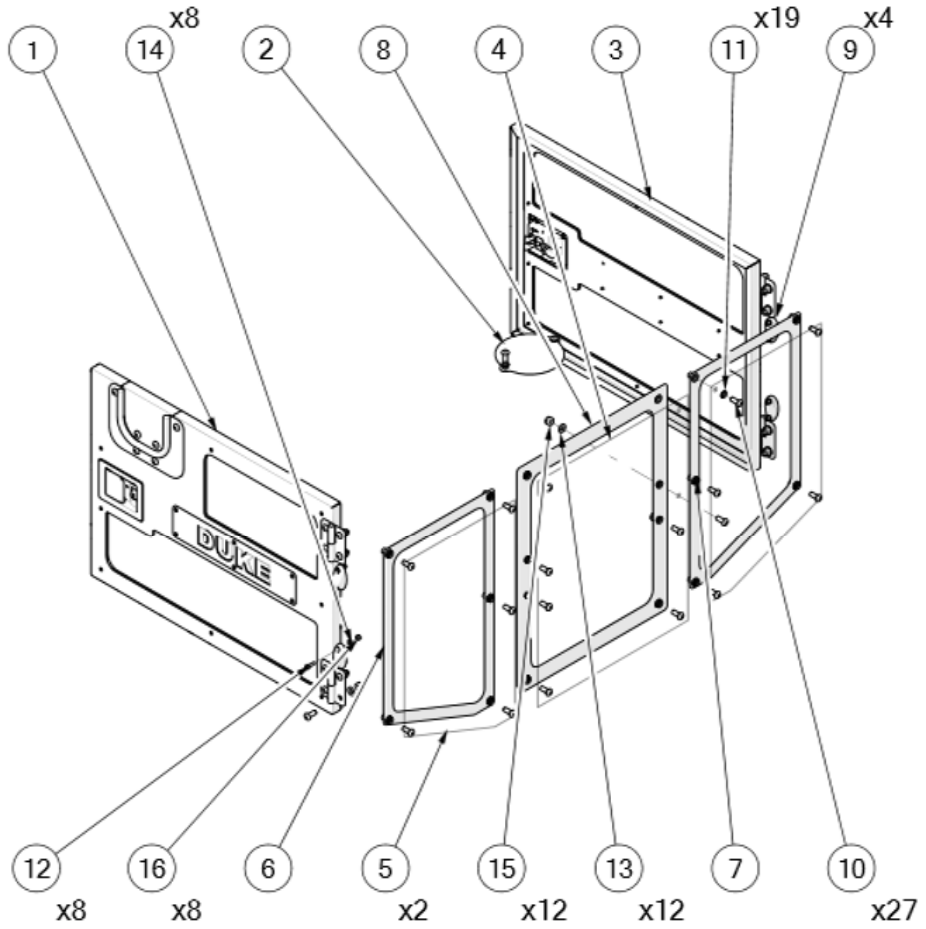
200105414 REAR CANOPY SUB-ASSEMBLY



200105414 REAR CANOPY SUB-ASSEMBLY

BOM ID	Number	Description	Qty
1	200100962	REAR CANOPY ANTI RATTLE MESH RUBBER	1
2	200100963	REAR CANOPY ANTI RATTLE MESH RUBBER	1
3	200100964	REAR CANOPY ANTI RATTLE MESH RUBBER	1
4	200100965	REAR CANOPY ANTI RATTLE MESH RUBBER	1
5	200105184	REAR CANOPY NS FABRICATION	1
6	200105185	REAR CANOPY MIDDLE	1
7	200105423	REAR CANOPY OS FABRICATION	1
8	200105438	EDGE TRIM [750 x 550]	2
9	C100G01120	CATCH HOOK	2
10	ST01048X881	M10 PLAIN WASHER	20
11	ST01096X881	M6 ORDINARY WASHER	4
12	ST01109X510	M10 NYLOC NUT	10
13	ST01975X743	M6 SOCKET HEAD CAP SCREW x 15 LG	4
14	ST04435X510	M6 NYLOC NUT	4
15	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	10

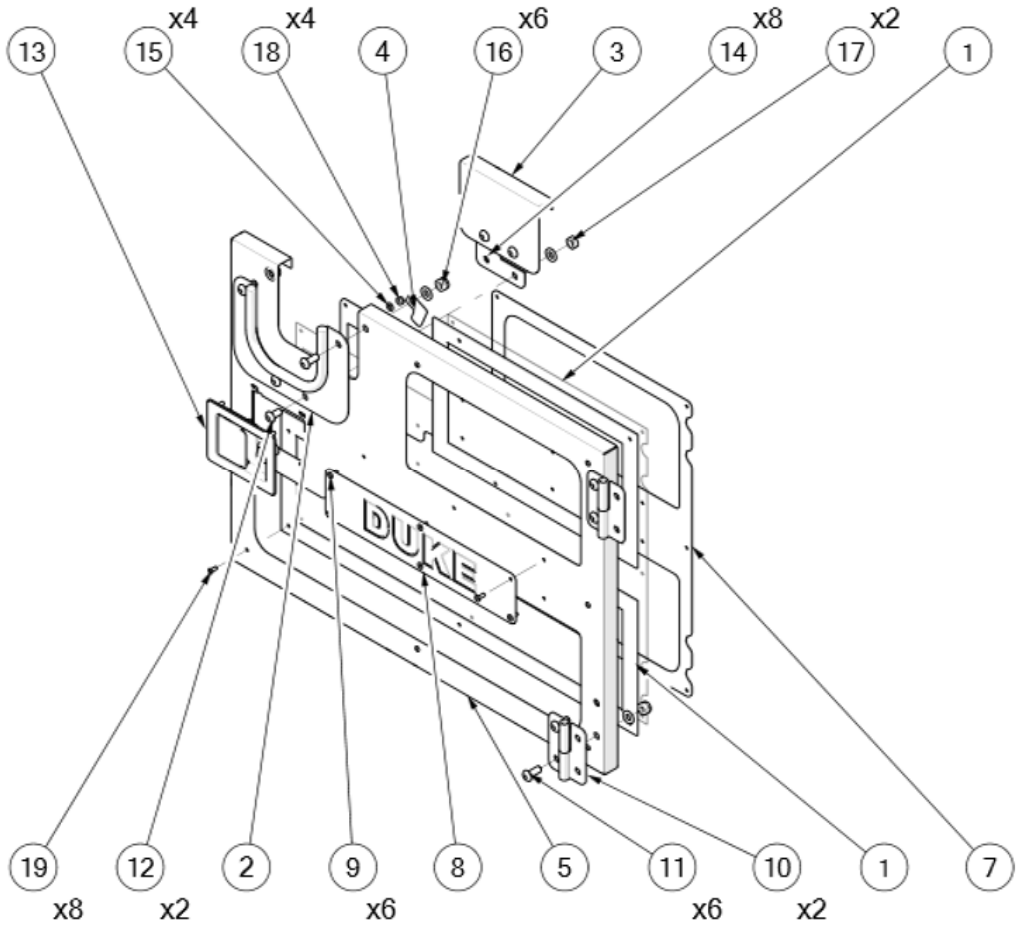
200105416 REAR CANOPY DOOR AND PANEL ASSEMBLY



200105416 REAR CANOPY DOOR AND PANEL ASSEMBLY

BOM ID	Number	Description	Qty
1	200105194	REAR CANOPY DOOR ASSEMBLY [NS]	1
2	200105338	COVER PLATE	1
3	200105428	REAR CANOPY DOOR ASSEMBLY [OS]	1
4	200105433	REAR CANOPY MESH	1
5	200105446	REAR CANOPY MESH	2
6	200105904	REAR CANOPY CLAMP PLATE [CW NUTSERTS]	1
7	200105905	REAR CANOPY CLAMP PLATE [CW NUTSERTS]	1
8	200105906	REAR CANOPY CLAMP PLATE [CW NUTSERTS]	1
9	900102100	RUBBER BUMP STOP [BF457]	4
10	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	27
11	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	19
12	ST00583X743	M6 CAP SCREW x 20 LG	8
13	ST01048X881	M10 PLAIN WASHER	12
14	ST01096X881	M6 ORDINARY WASHER	8
15	ST01109X510	M10 NYLOC NUT	12
16	ST04435X510	M6 NYLOC NUT	8

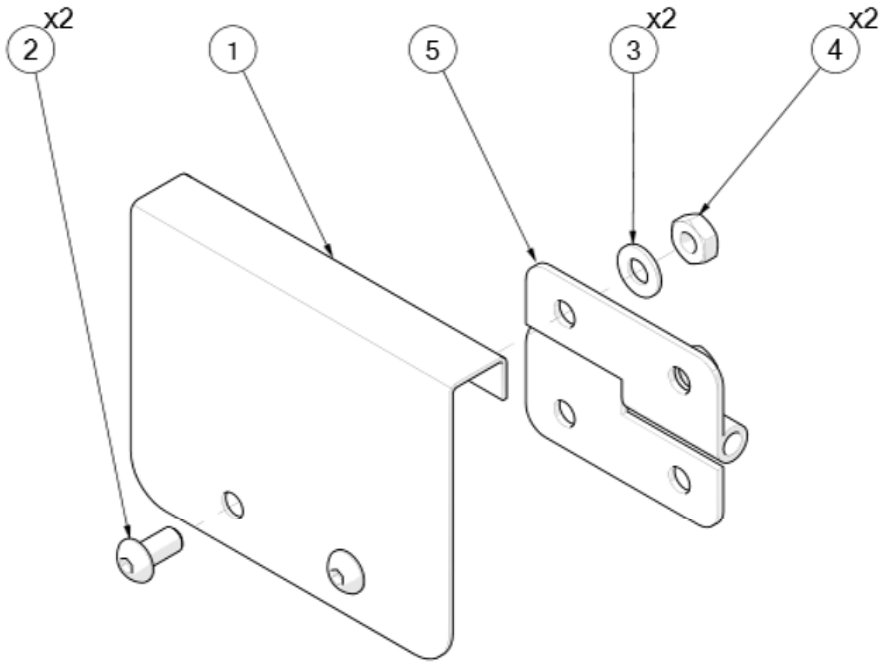
200105194 REAR CANOPY DOOR ASSEMBLY [NS]



200105194 REAR CANOPY DOOR ASSEMBLY [NS]

BOM ID	Number	Description	Qty
1	200100961	REAR CANOPY DOOR MESH RUBBER [NS]	1
2	200102243	UMBILICAL HOSE SUPPORT	1
3	200102246	UMBILICAL DOOR ASSY	1
4	200102247	LATCH PLATE	1
5	200105192	REAR CANOPY DOOR NS	1
6	200105427	REAR CANOPY DOOR MESH	1
7	200105431	REAR CANOPY DOOR CLAMP PLATE	1
8	200105437	NAME PLATE	1
9	900100128	4.8MM DIA S.S. POP RIVET 14MM	6
10	C10001135	LIFT OFF HINGE - R/H	2
11	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	6
12	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	2
13	C100G01673	PADDLE LATCH	1
14	ST01048X881	M10 PLAIN WASHER	8
15	ST01096X881	M6 ORDINARY WASHER	4
16	ST01109X510	M10 NYLOC NUT	6
17	ST01380X511	M10 THIN NUT	2
18	ST04435X510	M6 NYLOC NUT	4
19	ST12835X693	4.8mm DIA POP RIVET x 12mm LONG (CLOSED END)	8

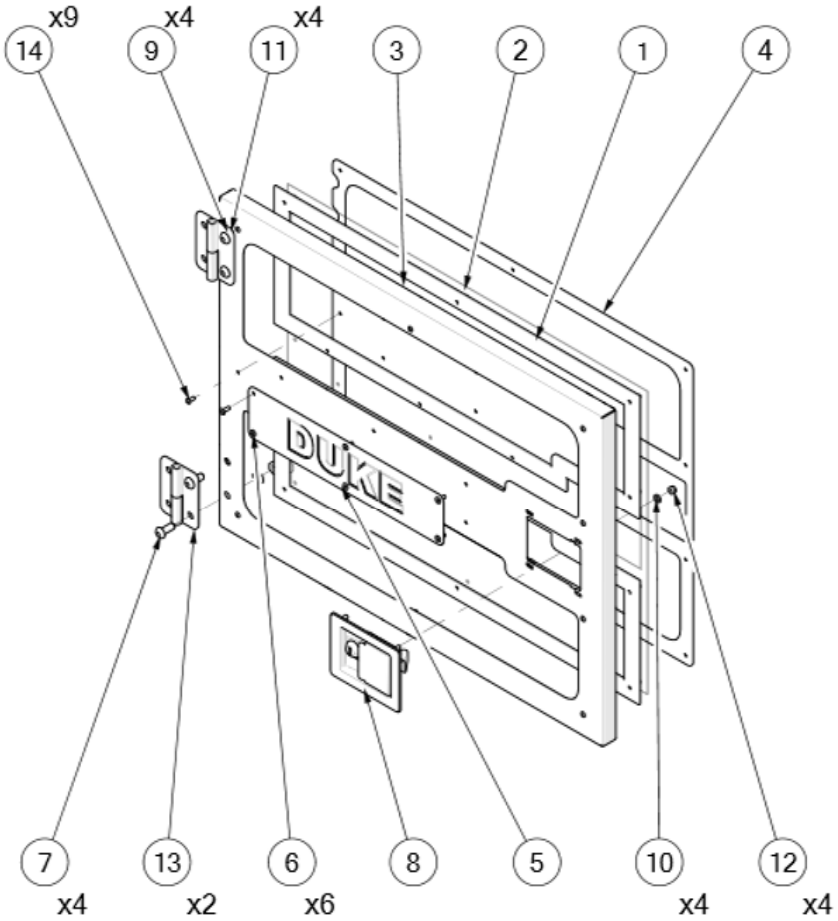
200102246 UMBILICAL DOOR ASSEMBLY



200102246 UMBILICAL DOOR ASSEMBLY

BOM ID	Number	Description	Qty
1	200102245	DOOR PLATE	1
2	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	2
3	ST01048X881	M10 PLAIN WASHER	2
4	ST01380X511	M10 THIN NUT	2
5	ST10554X344	LIFT OFF HINGE LH ASSY	1

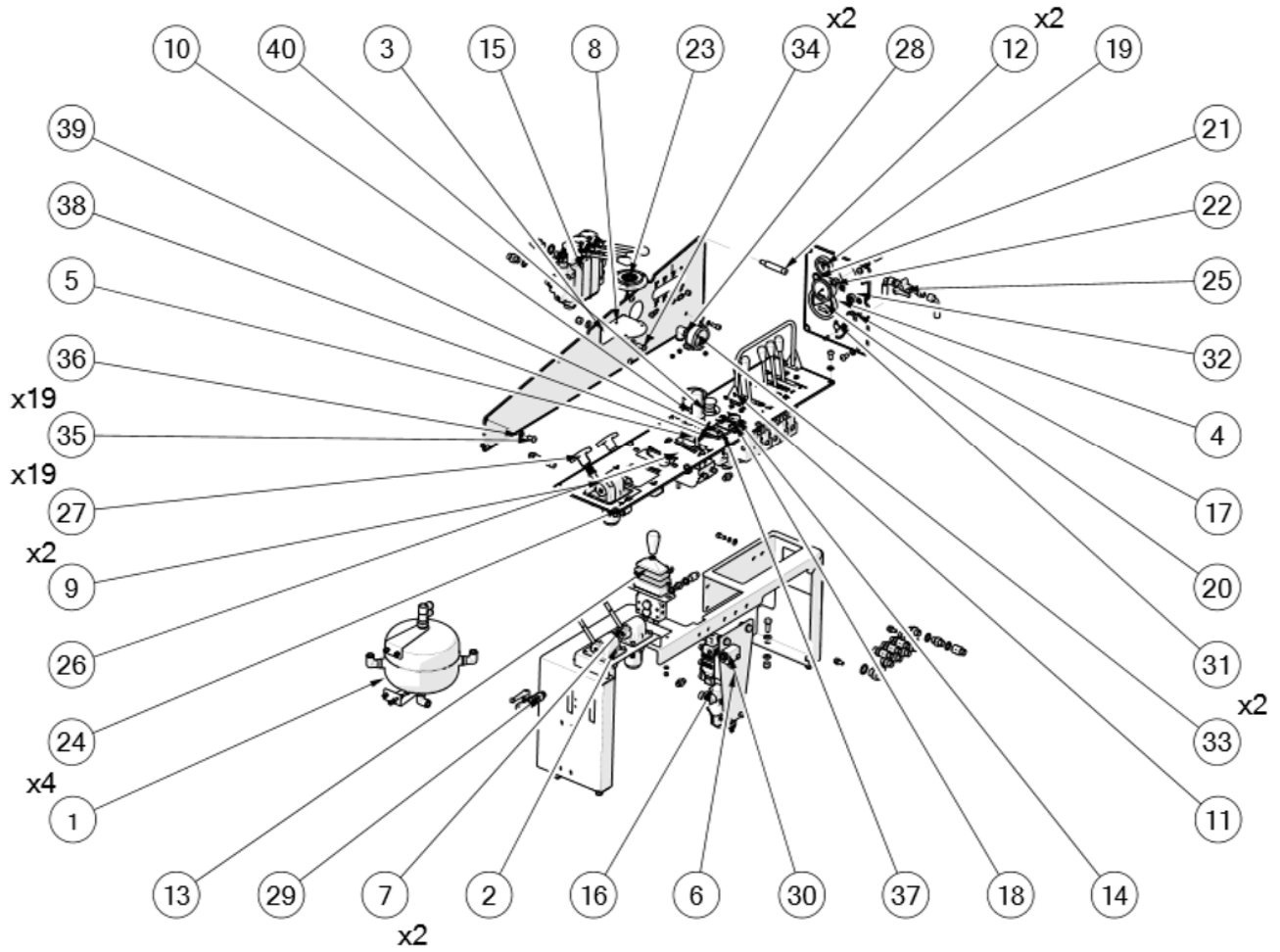
200105428 REAR CANOPY DOOR ASSEMBLY [OS]



200105428 REAR CANOPY DOOR ASSEMBLY [OS]

BOM ID	Number	Description	Qty
1	200100960	REAR CANOPY ANTI RATTLE DOOR MESH RUBBER [OS]	1
2	200105193	REAR CANOPY DOOR MESH	1
3	200105426	REAR CANOPY DOOR OS	1
4	200105432	REAR CANOPY DOOR CLAMP PLATE	1
5	200105437	NAME PLATE	1
6	900100128	4.8MM DIA S.S. POP RIVET 14MM	6
7	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	4
8	C100G01673	PADDLE LATCH	1
9	ST01048X881	M10 PLAIN WASHER	4
10	ST01096X881	M6 ORDINARY WASHER	4
11	ST01109X510	M10 NYLOC NUT	4
12	ST04435X510	M6 NYLOC NUT	4
13	ST10554X344	LIFT OFF HINGE LH ASSY	2
14	ST12835X693	4.8mm DIA POP RIVET x 12mm LONG (CLOSED END)	9

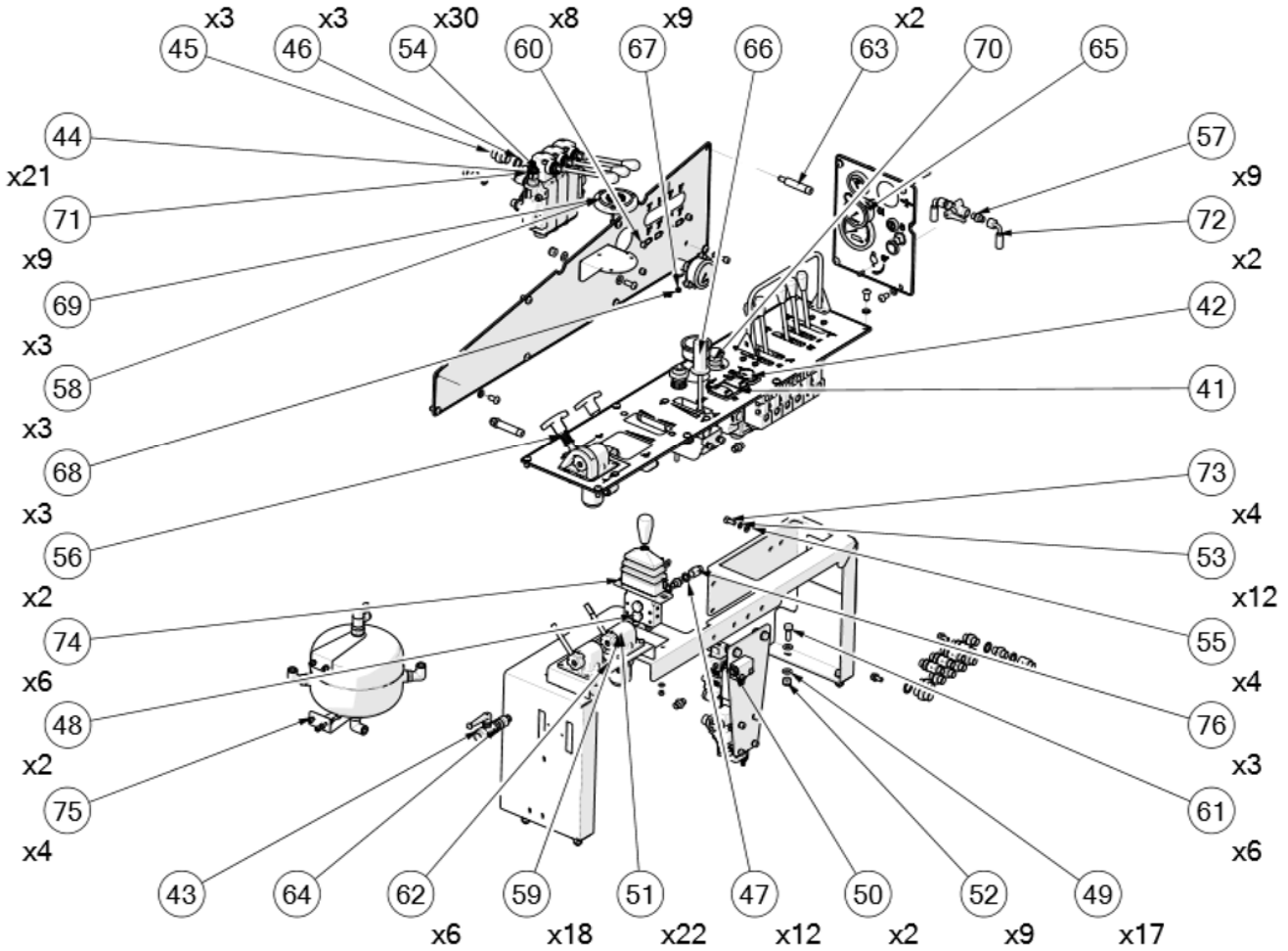
200105483 CONTROL CONSOLE ASSEMBLY



200105483 CONTROL CONSOLE ASSEMBLY

BOM ID	Number	Description	Qty
1	200105473	RECEIVER TANK ASSY	1
2	200105485	CONTROL CONSOLE VALVE RAIL FAB	1
3	200105486	INSTRUMENTS LEGEND	1
4	200105488	AIR PTO LEGEND	1
5	200105490	LEVER LEGEND	1
6	200105861	MOUNTING PLATE - HYD CONTROL VALVE R200	1
7	200105986	MODS TO AIR CONTROL VALVE	2
8	200105987	LEVEL GAUGE BRACKET	1
9	200106329	SAFETY LATCH ASSEMBLY	1
10	200109130	LEVER ASSY	1
11	200109138	WRIST BAR FAB V4-40 6 SECTION	1
12	200800329	CONSOLE COVER LOCK STOP [DANDO DUKE]	2
13	700100110	ONE BANK PILOT JOYSTICK CW ASSYMETRIC SPOOL	1
14	700100111	HYDRAULIC CONTROL VALVE 5 SPOOL [HYPRO]	1
15	700200131	HYDRAULIC CONTROL VALVE 0.375in 4 SPOOL	1
16	700200132	HYDRAULIC CONTROL VALVE [R200 T3E-DE 12-T4OE]	1
17	800100180	CIGARETTE LIGHTER SOCKET	1
18	800100245	ROTARY SWITCH QUICK CONNECT 3 WAY IP67 24V	1
19	800100259	FUEL GAUGE	1
20	800100260	TACHOMETER	1
21	800100261	LED PANEL MOUNT INDICATOR 22MM 12V IP65 (RED)	1
22	800100262	LED PANEL MOUNT INDICATOR 22MM 12V IP65 (ORANGE)	1
23	900100183	PLASTIC CIRCULAR LEVEL, Ø100mm, RANGE ±3°	1
24	900100208	0.25IN BSPP TO 12MM PUSH IN 90 DEG ELBOW	4
25	910100244	0.25in BSP PANEL MOUNT BALL VALVE	1
26	910100293	ENGINE THROTTLE 1.6M	1
27	910102195	T-KNOB S.S. M10 [WDS 8140]	2
28	910102196	0.25IN BSPP FEMALE TO 12MM PUSH IN 90 DEG ELBOW	1
29	910102199	0.375 BSPP FEMALE TO 12MM PUSH IN STRAIGHT	1
30	C1000063	SHUTTLE VALVE VUSF 140N-13Z	1
31	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	2
32	C100C0085	SEALED KEY SWITCH WITH INTEGRAL CONNECTOR	1
33	C100C01614	PRESSURE GAUGE (0-14 BAR)	1
34	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	2
35	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	19
36	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	19
37	C100G01664	ROCKER SWITCH PANEL MOUNTING PANEL 3 BANK	1
38	C100G01665	Illuminated Rectangular Black SPST Rocker Switch 12V 20A	1
39	C100G01666	V SERIES ROCKER SWITCH BLANKING PLUG	1
40	C100X0166	COMPACT E-STOP	1

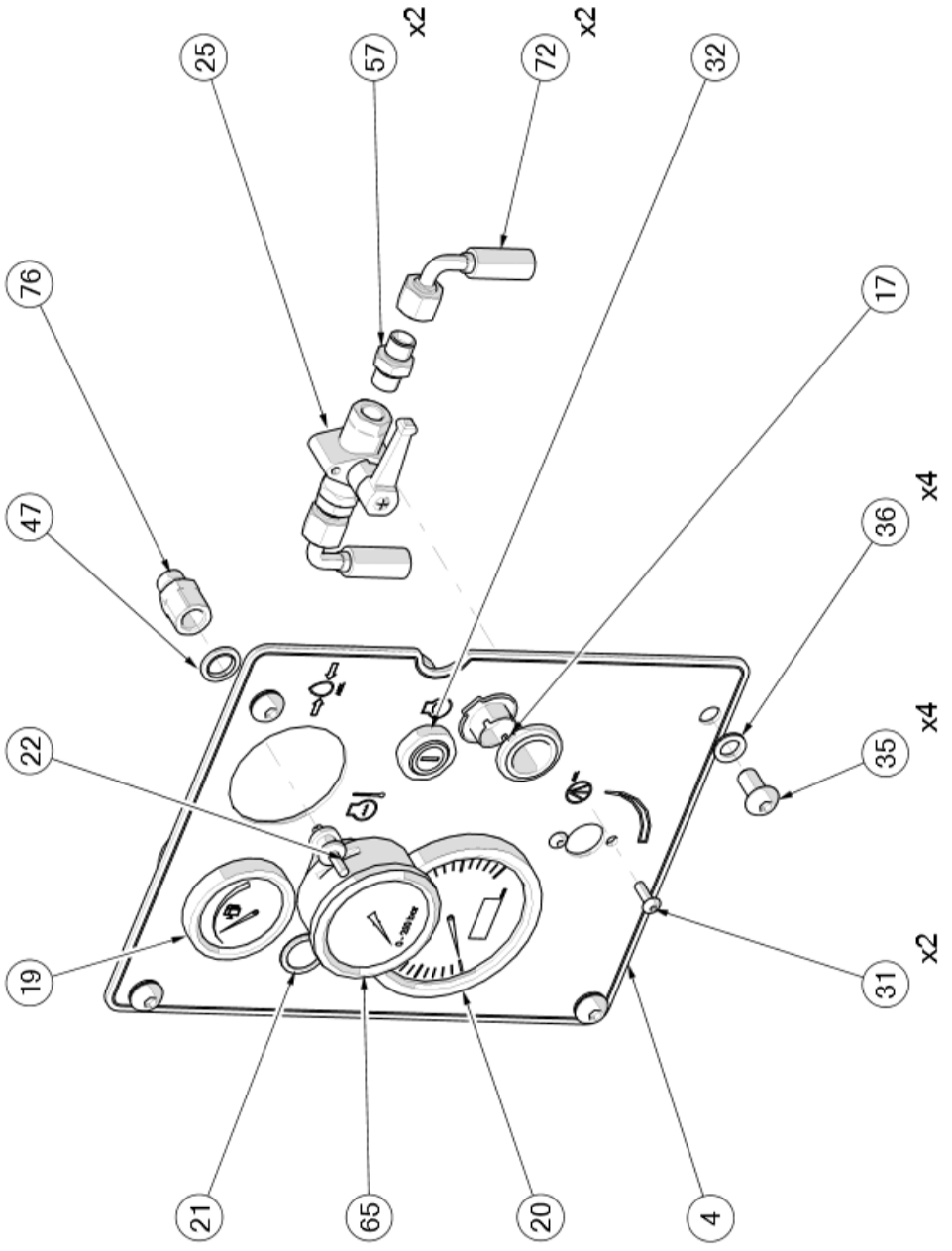
200105483 CONTROL CONSOLE ASSEMBLY



200105483 CONTROL CONSOLE ASSEMBLY

BOM ID	Number	Description	Qty
41	C100X0167	ROCKER SWITCH PANEL SPST OFF-(ON)	1
42	C102G01616	ROCKER SWITCH PANEL MOUNT 1 BANK	1
43	C115C0053	3/8" BSPP FEMALE BRASS LEVER OPERATED BALL VALVE	1
44	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	21
45	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	3
46	ST00246X328	1/2" BSP BONDED SEAL	3
47	ST00298X328	BONDED SEAL 1/4" BSP	12
48	ST00728X338	1/4" BSP HEX HEAD PLUG	2
49	ST01048X881	M10 PLAIN WASHER	17
50	ST01075X133	M6 HEX HD BOLT HT x 40 LONG.	2
51	ST01096X881	M6 PLAIN WASHER	22
52	ST01109X510	M10 NYLOC NUT	9
53	ST01146X885	M8 SPRING WASHER SINGLE COIL	12
54	ST01156X328	3/8"BSP BONDED SEAL [DOWTY]	30
55	ST01176X881	M8 PLAIN WASHER	4
56	ST01380X511	M10 THIN NUT	2
57	ST02282X326	1/4" BSP MALE/MALE STUD ADAPTER	9
58	ST04149X885	M5 SPRING WASHER	3
59	ST04435X510	M6 NYLOC NUT	18
60	ST06590X743	M8 SOCKET HEAD CAP SCREW x 20 LG	8
61	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	6
62	ST07729X715	M6 HEX HEAD SET SCREW x 20 LG.	6
63	ST07932X743	M10 SOCKET HEAD CAP SCREW x 80 LONG	2
64	ST08827X315	3/8" BSP MALE/MALE [60° CONE] BULKHEAD C/W LOCK NUT	1
65	ST08907X272	PRESSURE GAUGE (250 BAR)	1
66	ST08908X272	PRESSURE GAUGE (0-400 BAR)	1
67	ST09754X883	M5 PLAIN WASHER (BRIGHT)	9
68	ST09755X510	M5 NYLOC NUT	3
69	ST09807X743	M5 SOCKET HEAD CAP SCREW x 30 LONG	3
70	ST10288X224	EMERGENCY STOP LEGEND PLATE	1
71	ST11247X326	0.375IN M/F FIXED EXTENDED STUD ADAPTOR	9
72	ST11710X332	1/4" BSP 90 DEG. FEMALE SWEPT HOSE END	2
73	ST11946X133	M8 HEX HEAD BOLT (HT) x 20 LONG	4
74	ST12437X134	M6 ROOFING BOLT x 20 LONG	6
75	ST12607X715	M6 HEX HEAD SET SCREW HT x 20 LONG.	4
76	ST20332X326	1/4" BSPP x 1/4" BSPP M/F EXTENDED STUD ADAPTOR	3

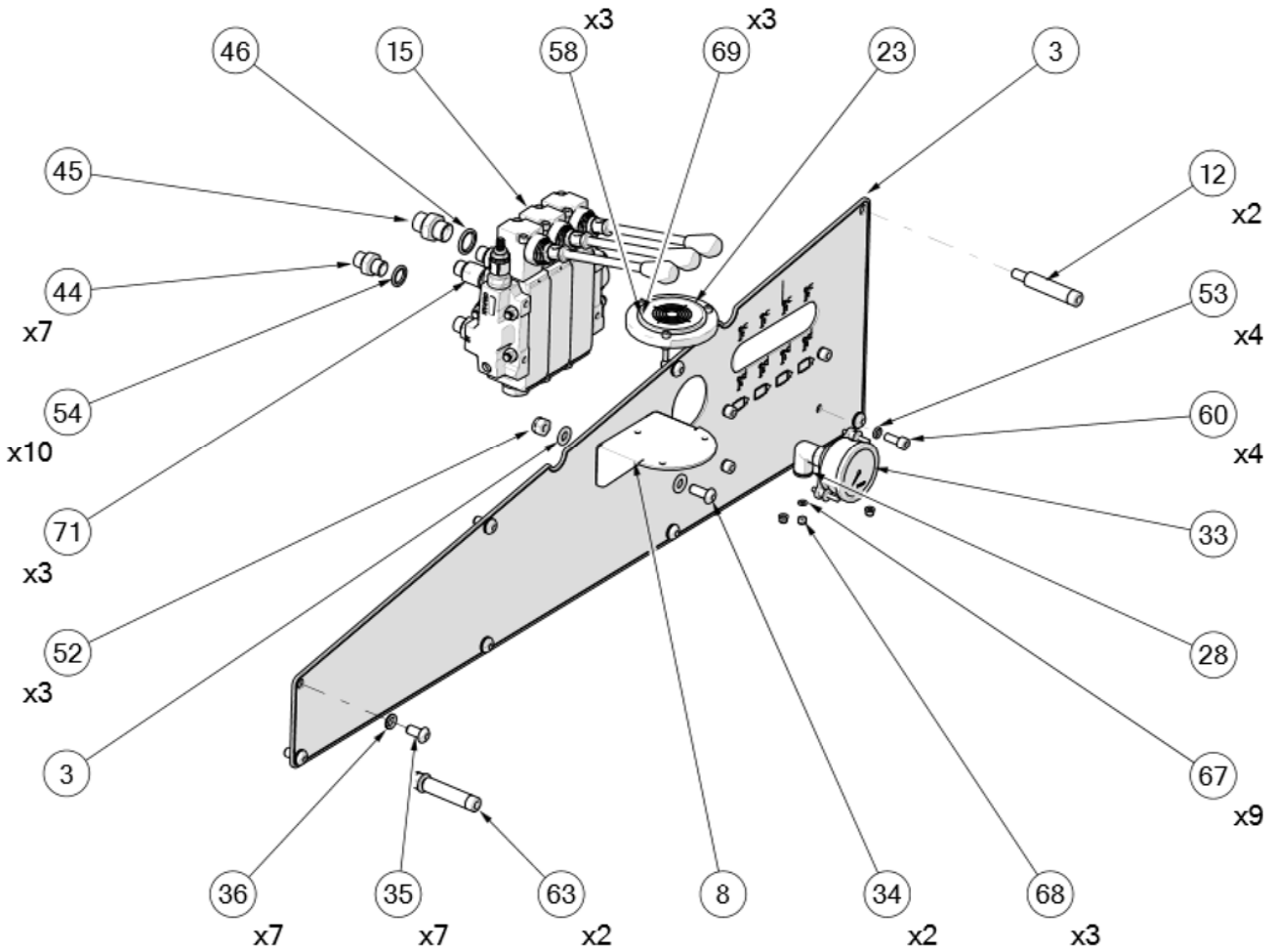
200105483 CONTROL CONSOLE ASSEMBLY 1



200105483 CONTROL CONSOLE ASSEMBLY 1

BOM ID	Number	Description	Qty
4	200105488	AIR PTO LEGEND	1
17	800100180	CIGARETTE LIGHTER SOCKET	1
19	800100259	FUEL GAUGE	1
20	800100260	TACHOMETER	1
21	800100261	LED PANEL MOUNT INDICATOR 22MM 12V IP65 (RED)	1
22	800100262	LED PANEL MOUNT INDICATOR 22MM 12V IP65 (ORANGE)	1
25	910100244	0.25in BSP PANEL MOUNT BALL VALVE	1
31	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	2
32	C100C0085	SEALED KEY SWITCH WITH INTEGRAL CONNECTOR	1
35	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	4
36	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	4
47	ST00298X328	BONDED SEAL 1/4" BSP	1
57	ST02282X326	1/4" BSP MALE/MALE STUD ADAPTER	2
65	ST08907X272	PRESSURE GAUGE (250 BAR)	1
72	ST11710X332	1/4" BSP 90 DEG. FEMALE SWEPT HOSE END	2
76	ST20332X326	1/4" BSPP x 1/4" BSPP M/F EXTENDED STUD ADAPTOR	1

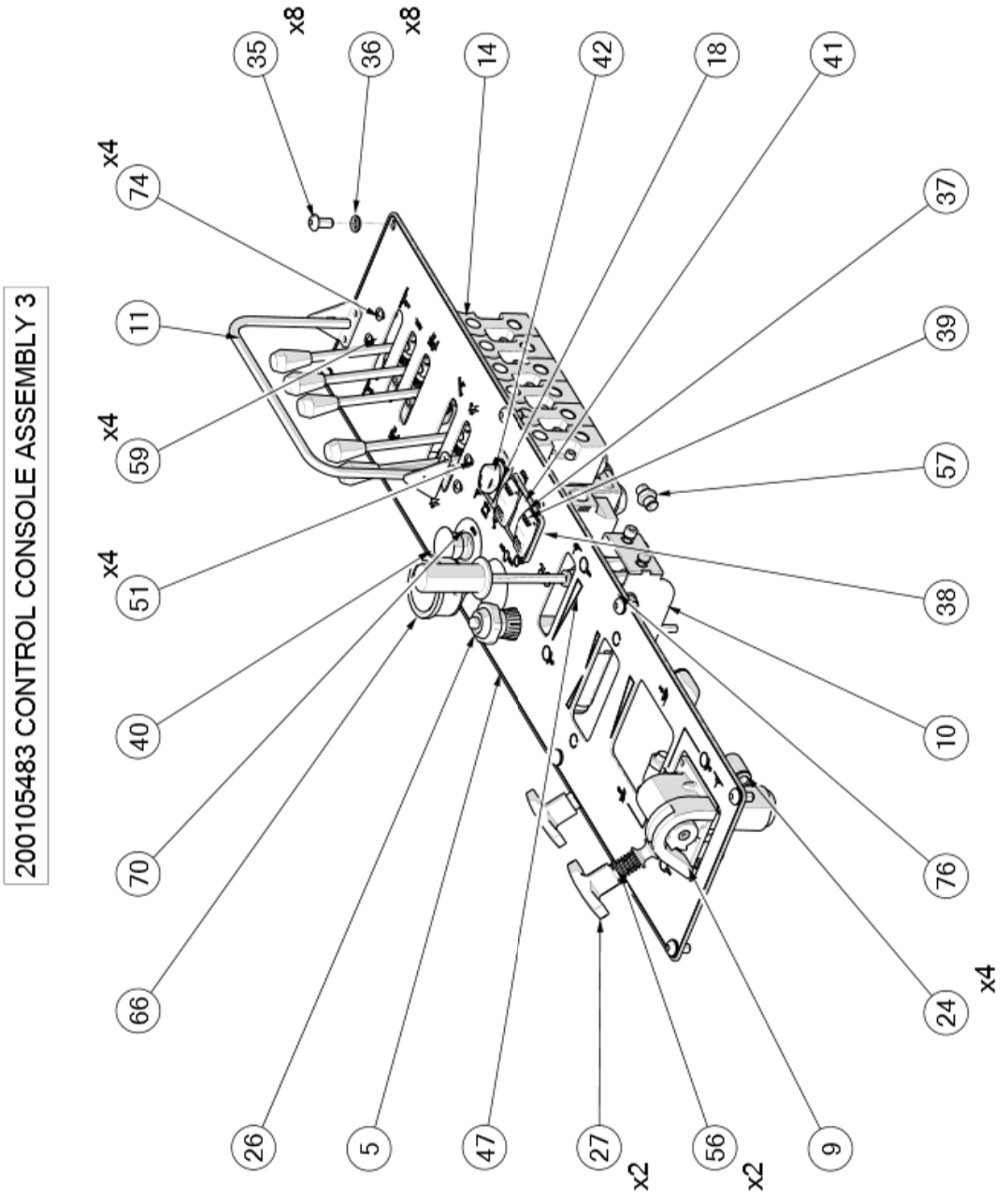
200105483 CONTROL CONSOLE ASSEMBLY 2



200105483 CONTROL CONSOLE ASSEMBLY 2

BOM ID	Number	Description	Qty
3	200105486	INSTRUMENTS LEGEND	1
8	200105987	LEVEL GAUGE BRACKET	1
12	200800329	CONSOLE COVER LOCK STOP [DANDO DUKE]	2
15	700200131	HYDRAULIC CONTROL VALVE 0.375in 4 SPOOL	1
23	900100183	PLASTIC CIRCULAR LEVEL, Ø100mm, RANGE ±3°	1
28	910102196	0.25IN BSPP FEMALE TO 12MM PUSH IN 90 DEG ELBOW [AIR4U CDPLF1202N]	1
33	C100C01614	PRESSURE GAUGE (0-14 BAR)	1
34	C100G00910	M10 S.S. HEX SOC BUTTON HEAD SCREW X 25 LG	2
35	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	7
36	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	7
44	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	7
45	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	1
46	ST00246X328	1/2" BSP BONDED SEAL	1
49	ST01048X881	M10 PLAIN WASHER	5
52	ST01109X510	M10 NYLOC NUT	3
53	ST01146X885	M8 SPRING WASHER SINGLE COIL	4
54	ST01156X328	3/8"BSP BONDED SEAL [DOWTY]	10
58	ST04149X885	M5 SPRING WASHER	3
60	ST06590X743	M8 SOCKET HEAD CAP SCREW x 20 LG	4
63	ST07932X743	M10 SOCKET HEAD CAP SCREW x 80 LONG	2
67	ST09754X883	M5 PLAIN WASHER (BRIGHT)	9
68	ST09755X510	M5 NYLOC NUT	3
69	ST09807X743	M5 SOCKET HEAD CAP SCREW x 30 LONG	3
71	ST11247X326	0.375IN M/F FIXED EXTENDED STUD ADAPTOR	3

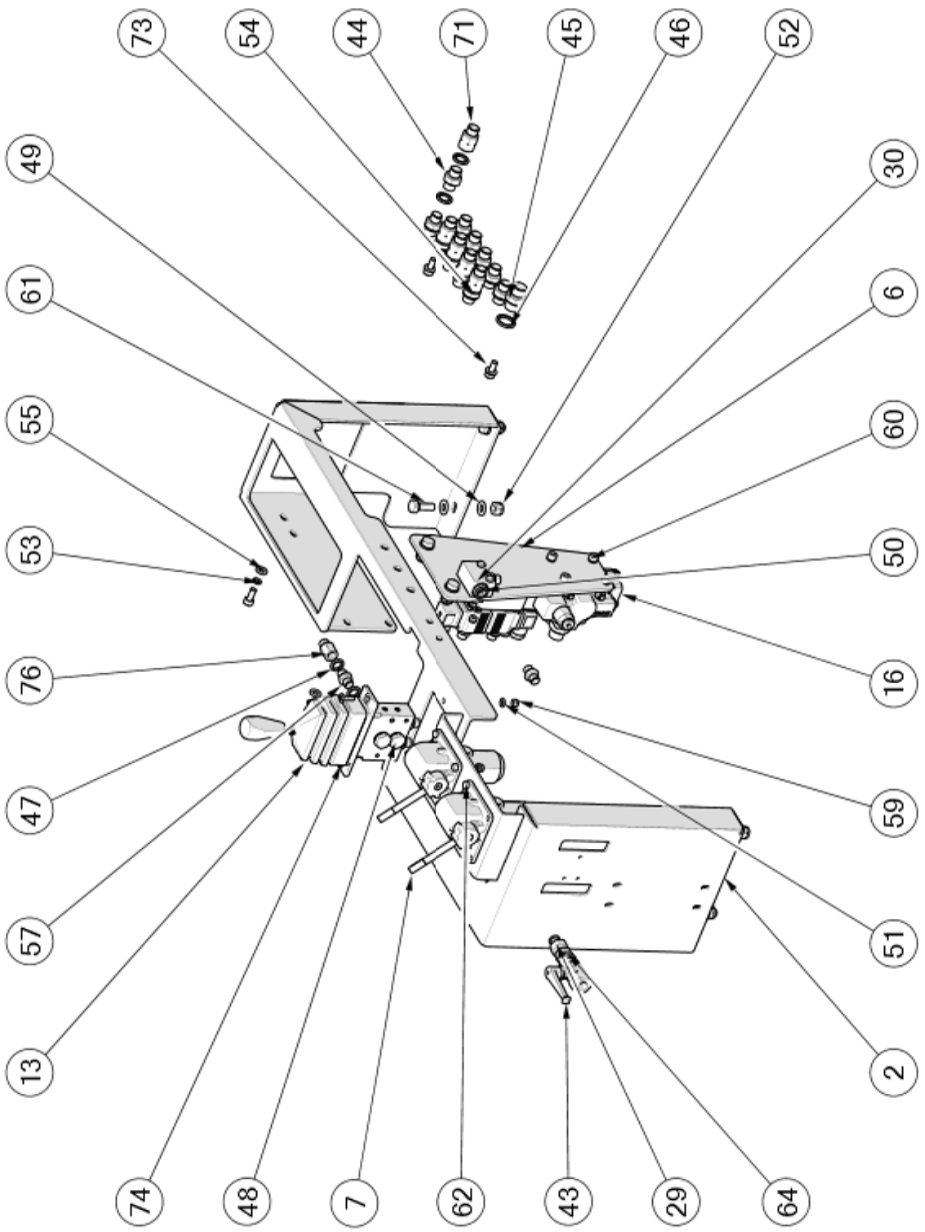
200105483 CONTROL CONSOLE ASSEMBLY 3



200105483 CONTROL CONSOLE ASSEMBLY 3

BOM ID	Number	Description	Qty
5	200105490	LEVER LEGEND	1
9	200106329	SAFETY LATCH ASSEMBLY	1
10	200109130	LEVER ASSY	1
11	200109138	WRIST BAR FAB V4-40 6 SECTION	1
14	700100111	HYDRAULIC CONTROL VALVE 5 SPOOL [HYPRO]	1
18	800100245	ROTARY SWITCH QUICK CONNECT 3 WAY IP67 24V	1
24	900100208	0.25IN BSPP TO 12MM PUSH IN 90 DEG ELBOW	4
26	910100293	ENGINE THROTTLE 1.6M	1
27	910102195	T-KNOB S.S. M10 [WDS 8140]	2
35	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	8
36	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	8
37	C100G01664	ROCKER SWITCH PANEL MOUNTING PANEL 3 BANK	1
38	C100G01665	Illuminated Rectangular Black SPST Rocker Switch 12V 20A	1
39	C100G01666	V SERIES ROCKER SWITCH BLANKING PLUG (RS - 881-5649)	1
40	C100X0166	COMPACT E-STOP (RS 492-7268)	1
41	C100X0167	ROCKER SWITCH PANEL SPST OFF-(ON)	1
42	C102G01616	ROCKER SWITCH PANEL MOUNT 1 BANK (RS 881-5718)	1
47	ST00298X328	BONDED SEAL 1/4" BSP	1
51	ST01096X881	M6 PLAIN WASHER	4
56	ST01380X511	M10 THIN NUT	2
57	ST02282X326	1/4" BSP MALE/MALE STUD ADAPTER	1
59	ST04435X510	M6 NYLOC NUT	4
66	ST08908X272	PRESSURE GAUGE (0-400 BAR)	1
70	ST10288X224	EMERGENCY STOP LEGEND PLATE	1
74	ST12437X134	M6 ROOFING BOLT x 20 LONG	4
76	ST20332X326	1/4" BSPP x 1/4" BSPP M/F EXTENDED STUD ADAPTOR	1

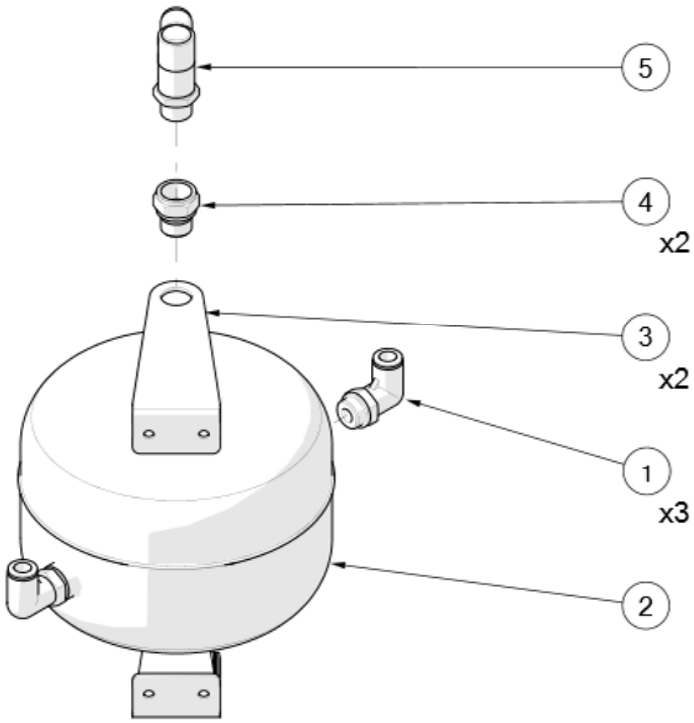
200105483 CONTROL CONSOLE ASSEMBLY 4



200105483 CONTROL CONSOLE ASSEMBLY 4

BOM ID	Number	Description	Qty
2	200105485	CONTROL CONSOLE VALVE RAIL FAB	1
6	200105861	MOUNTING PLATE - HYD CONTROL VALVE R200	1
7	200105986	MODS TO AIR CONTROL VALVE	2
13	700100110	ONE BANK PILOT JOYSTICK CW ASSYMETRIC SPOOL	1
16	700200132	HYDRAULIC CONTROL VALVE [R200 T3E-DE 12-T4OE]	1
29	910102199	0.375 BSPP FEMALE TO 12MM PUSH IN STRAIGHT [AIR4U CDPCF12G03]	1
30	C1000063	SHUTTLE VALVE VUSF 140N-13Z	1
43	C115C0053	3/8" BSPP FEMALE BRASS LEVER OPERATED BALL VALVE [IES IT90-38]	1
44	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	14
45	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	2
46	ST00246X328	1/2" BSP BONDED SEAL	2
47	ST00298X328	BONDED SEAL 1/4" BSP	10
48	ST00728X338	1/4" BSP HEX HEAD PLUG	2
49	ST01048X881	M10 PLAIN WASHER	12
50	ST01075X133	M6 HEX HD BOLT HT x 40 LONG.	2
51	ST01096X881	M6 PLAIN WASHER	10
52	ST01109X510	M10 NYLOC NUT	6
53	ST01146X885	M8 SPRING WASHER SINGLE COIL	8
54	ST01156X328	3/8"BSP BONDED SEAL [DOWTY]	20
55	ST01176X881	M8 PLAIN WASHER	4
57	ST02282X326	1/4" BSP MALE/MALE STUD ADAPTER	6
59	ST04435X510	M6 NYLOC NUT	10
60	ST06590X743	M8 SOCKET HEAD CAP SCREW x 20 LG	4
61	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	6
62	ST07729X715	M6 HEX HEAD SET SCREW x 20 LG.	6
64	ST08827X315	3/8" BSP MALE/MALE [60° CONE] BULKHEAD C/W LOCK NUT	1
71	ST11247X326	0.375IN M/F FIXED EXTENDED STUD ADAPTOR	6
73	ST11946X133	M8 HEX HEAD BOLT (HT) x 20 LONG	4
74	ST12437X134	M6 ROOFING BOLT x 20 LONG	2
76	ST20332X326	1/4" BSPP x 1/4" BSPP M/F EXTENDED STUD ADAPTOR	1

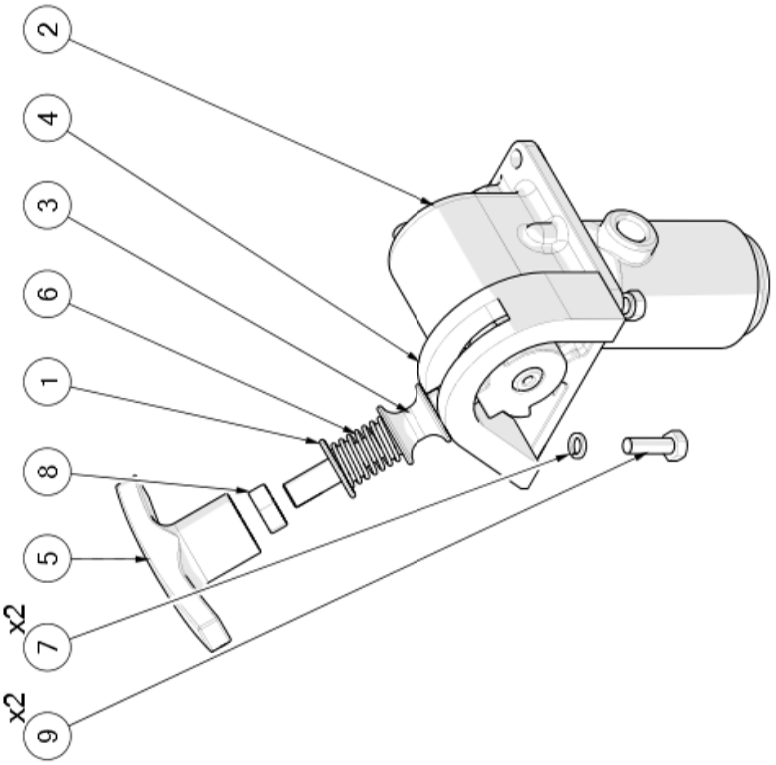
200105473 RECEIVER TANK ASSEMBLY



200105473 RECEIVER TANK ASSEMBLY

BOM ID	Number	Description	Qty
1	900100209	0.5IN BSPP TO 12MM PUSH IN 90 DEG ELBOW	3
2	910100231	5L AIR RECEIVER TANK	1
3	910100241	RECEIVER MOUNTING BRACKET	2
4	910100242	RECEIVER MOUNTING FITTING	2
5	910102200	0.5IN BSPP TO 12MM PUSH IN DOUBLE UNIVERSAL ELBOW	1

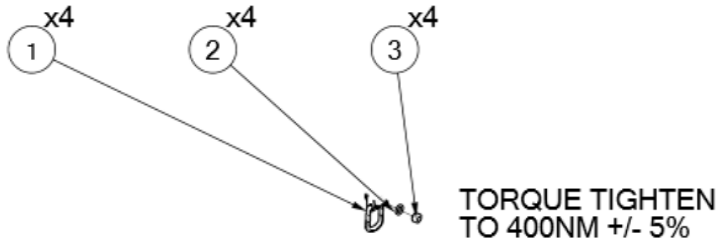
200106329 SAFETY LATCH ASSEMBLY



200106329 SAFETY LATCH ASSEMBLY

BOM ID	Number	Description	Qty
1	200105549	INDEPENDENT SAFETY LATCH TOP PLATE	1
2	200105986	MODS TO AIR CONTROL VALVE	1
3	200106330	SAFETY LATCH LEVER	1
4	200106914	SAFTEY LATCH BRACKET	1
5	910102195	T-KNOB S.S. M10 [WDS 8140]	1
6	910200303	LOCKING LEVER SPRING	1
7	ST01179X885	M6 SPRING WASHER	2
8	ST01380X511	M10 THIN NUT	1
9	ST07729X715	M6 HEX HEAD SET SCREW x 20 LG.	2

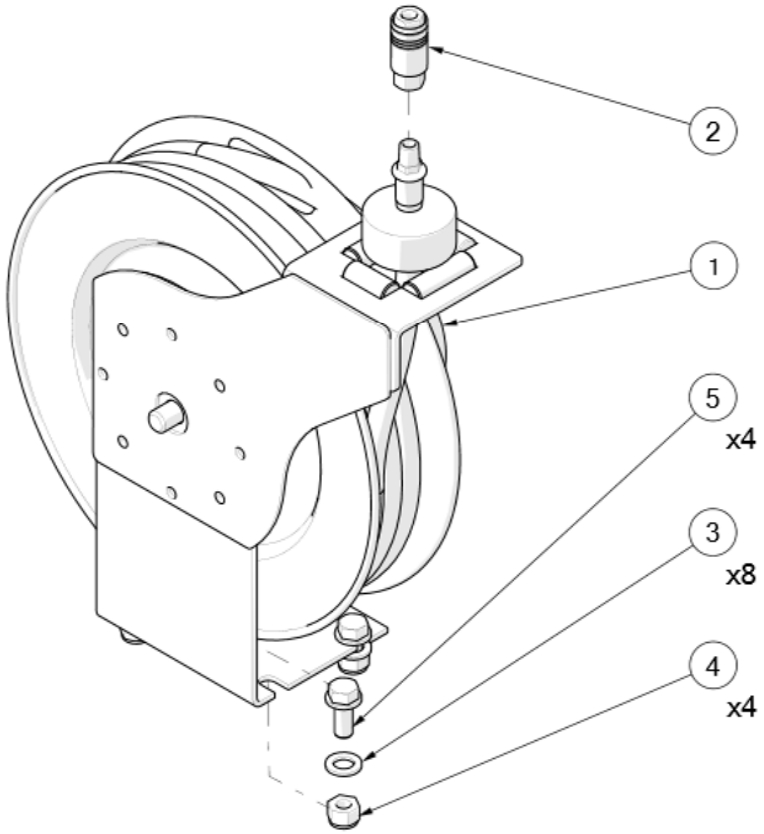
200105452 LIFTING EYE ASSEMBLY



200105452 LIFTING EYE ASSEMBLY

BOM ID	Number	Description	Qty
1	200101160	3.5T LIFTING EYE (RUD VLBG-PLUS)	4
2	910100255	M20 WASHER EN 14399-T6-21 (DIN 6916) ZINC PLATED WITH CRACK DETECTION (RUD 7990536)	4
3	910100256	NUT DIN 980-V M20 CRACK DETECTED (RUD 8801024)	4

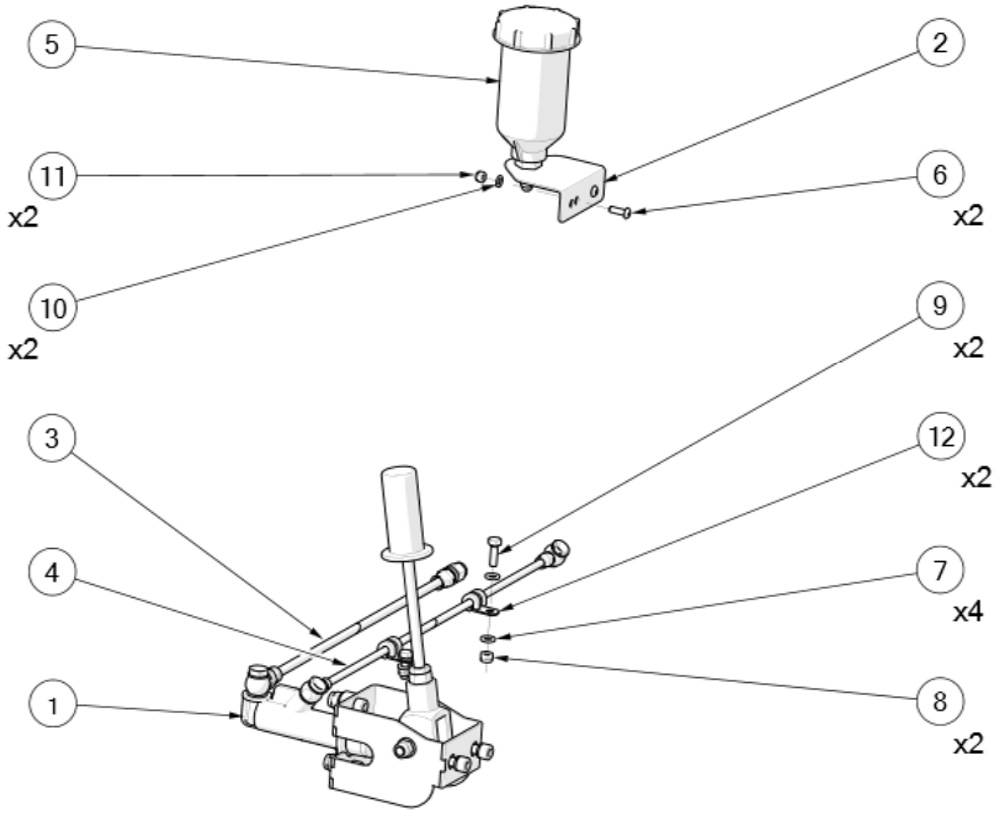
200105460 AIR HOSE REEL ASSEMBLY



200105460 AIR HOSE REEL ASSEMBLY

BOM ID	Number	Description	Qty
1	200105448	RETRACTABLE AIR HOSE REEL 8M	1
2	910100228	0.25in PNEUMATIC SNAP FIT FEMALE	1
3	ST00788X881	M12 PLAIN WASHER	8
4	ST06828X523	M12 NYLOC NUT	4
5	ST07889X133	M12 HEX HEAD BOLT x 30 LONG	4

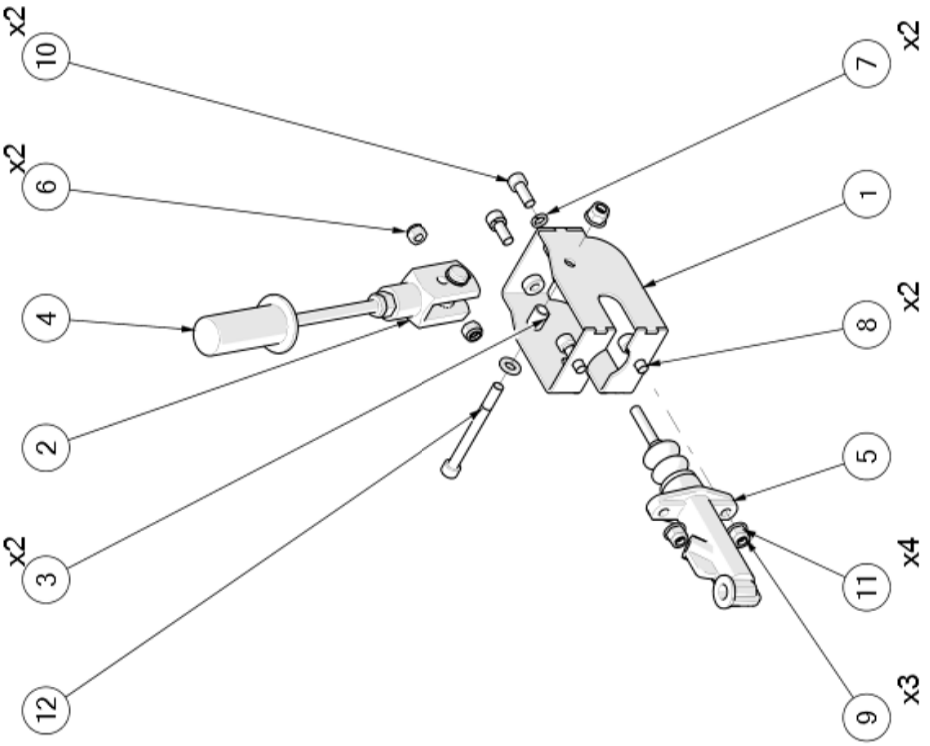
200109131 FINE CONTROL BRAKE ASSEMBLY



200109131 FINE CONTROL BRAKE ASSEMBLY

BOM ID	Number	Description	Qty
1	200109130	LEVER ASSY	1
2	200109156	ALUMINIUM RESERVOIR BRACKET	1
3	200115119	BRAKE RESERVOIR HOSE ASSEMBLY	1
4	200115120	BRAKE CALIPER HOSE ASSEMBLY	1
5	910102230	REMOTE BRAKE FLUID RESERVOIR (0.4375IN X 20 UNF MALE)	1
6	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	2
7	ST01096X881	M6 PLAIN WASHER	4
8	ST04435X510	M6 NYLOC NUT	2
9	ST07298X133	M6 HEX HEAD BOLT (HT) x 20 LONG	2
10	ST09754X883	M5 PLAIN WASHER - BRIGHT	2
11	ST09755X510	M5 NYLOC NUT	2
12	ST11197X163	6mm "P" CLIP RUBBER LINED JCS	2

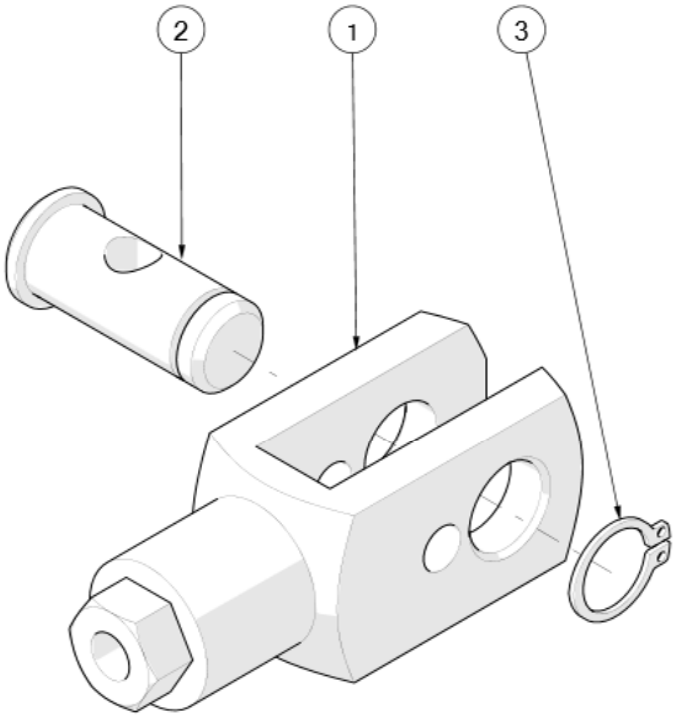
200109130 LEVER ASSEMBLY



200109130 LEVER ASSEMBLY

BOM ID	Number	Description	Qty
1	200108327	MOUNTING BRACKET FABRICATION (BRAKE MASTER CYLINDER)	1
2	200109136	FINE CONTROL CLEVIS ASSY	1
3	200109146	CLEVIS SPACER	2
4	700200149	HYDRAULIC LEVER WITH MOMENTARY PUSH BUTTON SWTCH ON-OFF NC [SYSTEM 910 - 1701X2525]	1
5	910102231	GIRLING MASTER CYLINDER REMOTE 0.625IN BORE	1
6	910102247	0.3125IN UNF NYLOC NUT	2
7	ST01146X885	M8 SPRING WASHER SINGLE COIL	2
8	ST01813X743	M8 SOCKET HEAD CAPSCREW x 25 LONG	2
9	v2ST04379X510	M8 NYLOC NUT	3
10	ST06590X743	M8 SOCKET HEAD CAP SCREW x 20 LG	2
11	ST10375X883	M8 NB ORDINARY WASHER (ZINC PLATED)	4
12	ST11252X743	M8 SOCKET HEAD CAP SCREW x 85 LONG	1

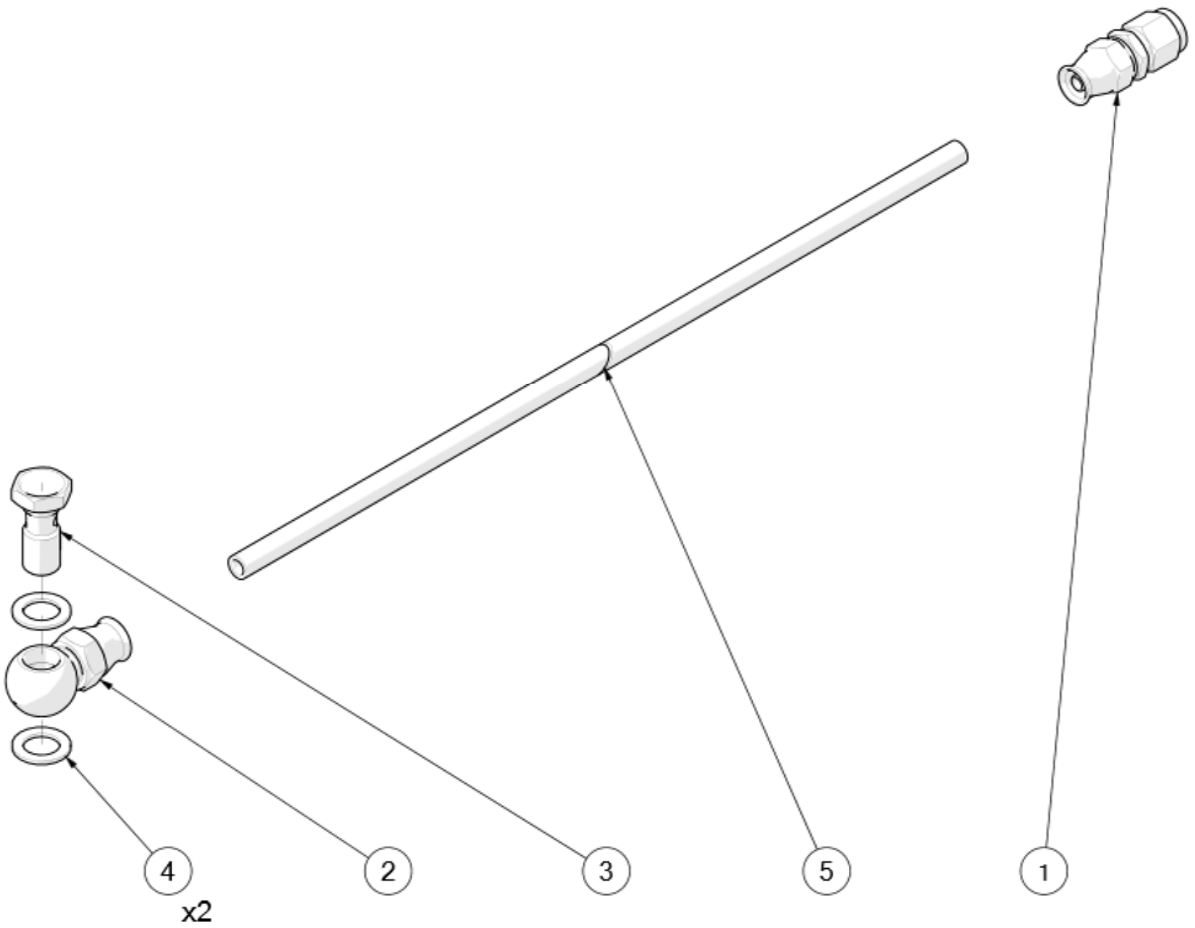
200109136 FINE CONTROL CLEVIS ASSEMBLY



200109136 FINE CONTROL CLEVIS ASSEMBLY

BOM ID	Number	Description	Qty
1	200109134	FINE CONTROL CLEVIS	1
2	200109137	FINE CONTROL CLEVIS PIN	1
3	910102232	16 DIA STANDARD EXTERNAL CIRCLIP DIN 471	1

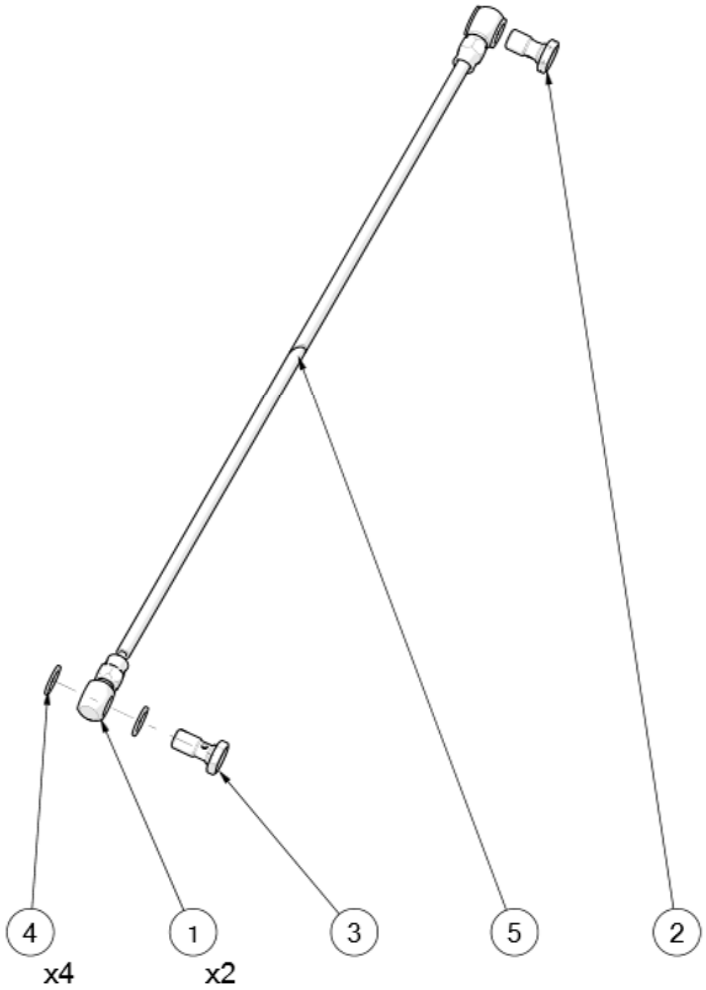
200115119 BRAKE RESERVOIR HOSE ASSEMBLY



200115119 BRAKE RESERVOIR HOSE ASSEMBLY

BOM ID	Number	Description	Qty
1	910200283	0.4375 X 20 UNF GOODRIDGE STRAIGHT FEMALE BRAKE FITTING [600-4 HOSE]	1
2	910200284	0.4375IN GOODRIDGE BRAKE LINE BANJO [600-4 HOSE]	1
3	910200286	0.4375IN X 20 UNF GOODRIDGE BANJO BOLT	1
4	910200289	0.4375IN GOODRIDGE COPPER WASHER	2
5	910200291	GOODRIDGE 600-4 BRAKE HOSE	1

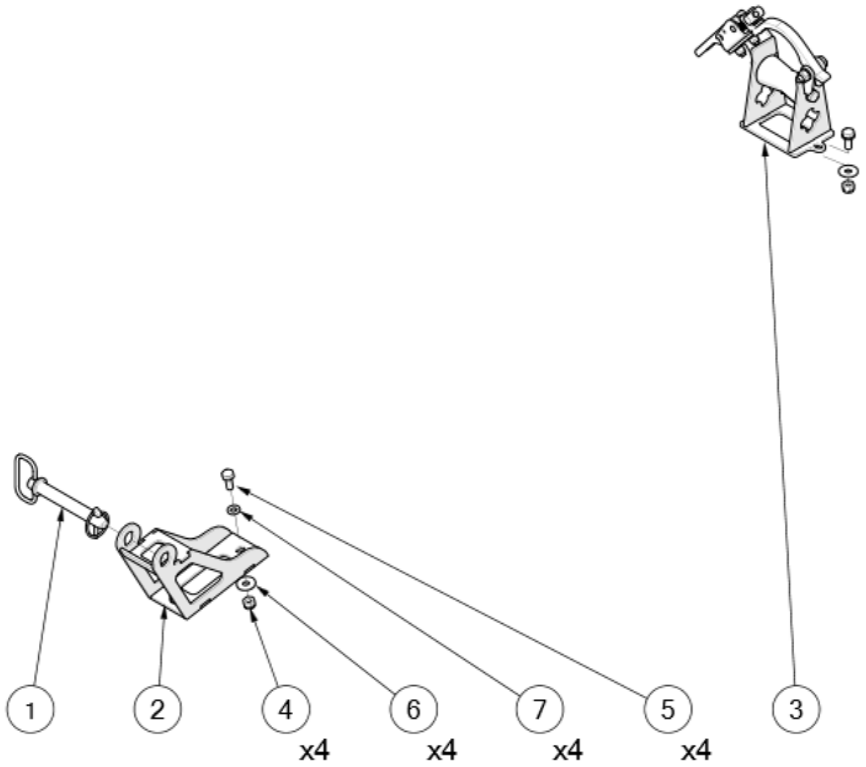
200115120 BRAKE CALIPER HOSE ASSEMBLY



200115120 BRAKE CALIPER HOSE ASSEMBLY

BOM ID	Number	Description	Qty
1	910200285	0.375IN GOODRIDGE BRAKE LINE BANJO [600-3 HOSE]	2
2	910200287	M10 X 1 GOODRIDGE BANJO BOLT	1
3	910200288	0.375IN X 24 UNF GOODRIDGE BANJO BOLT	1
4	910200290	0.375IN GOODRIDGE COPPER WASHER	4
5	910200292	GOODRIDGE 600-3 BRAKE HOSE	1

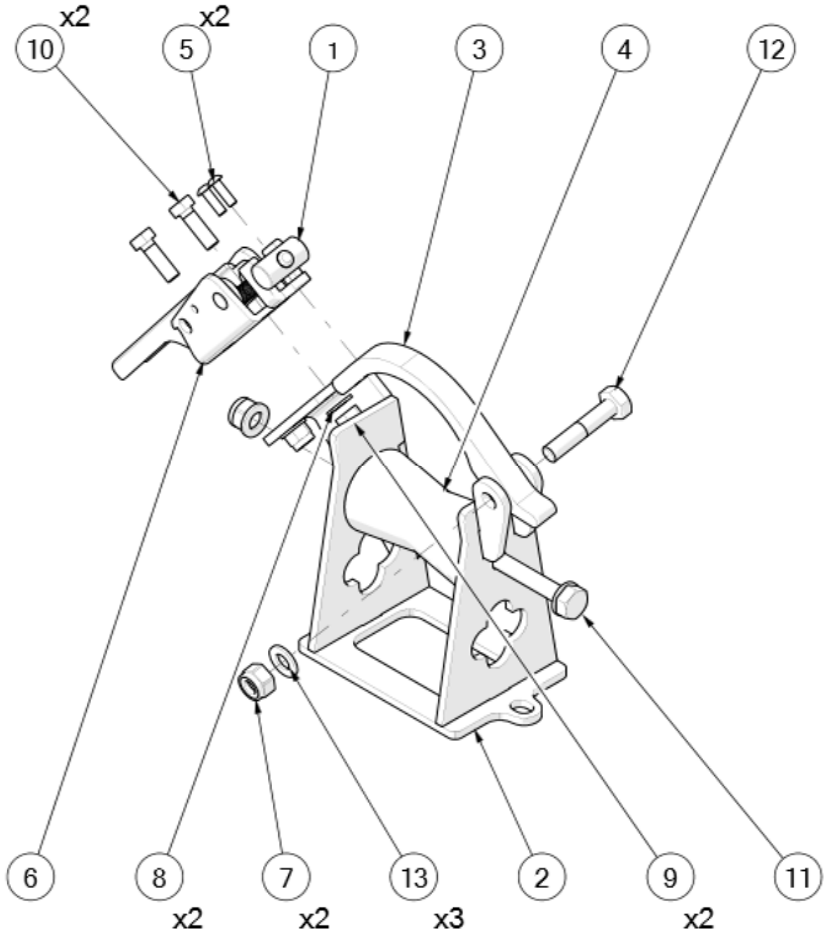
200108353 STOWAGE ASSEMBLY - SPREADER BAR



200108353 STOWAGE ASSEMBLY - SPREADER BAR

BOM ID	Number	Description	Qty
1	200101121	20 DIA HITCH PIN 145 LG, CW LINCH PIN & CHAIN	1
2	200108343	STOWAGE BRACKET FABRICATION	1
3	200108355	CLAMP BRACKET ASSEMBLY - SPREADER BAR	1
4	ST01109X510	M10 NYLOC NUT	4
5	ST07886X715	M10 HEX HEAD SET SCREW HT x 25 LG.	4
6	ST10208X898	M10 NB EXTRA LARGE PLAIN WASHER BRIGHT	4
7	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	4

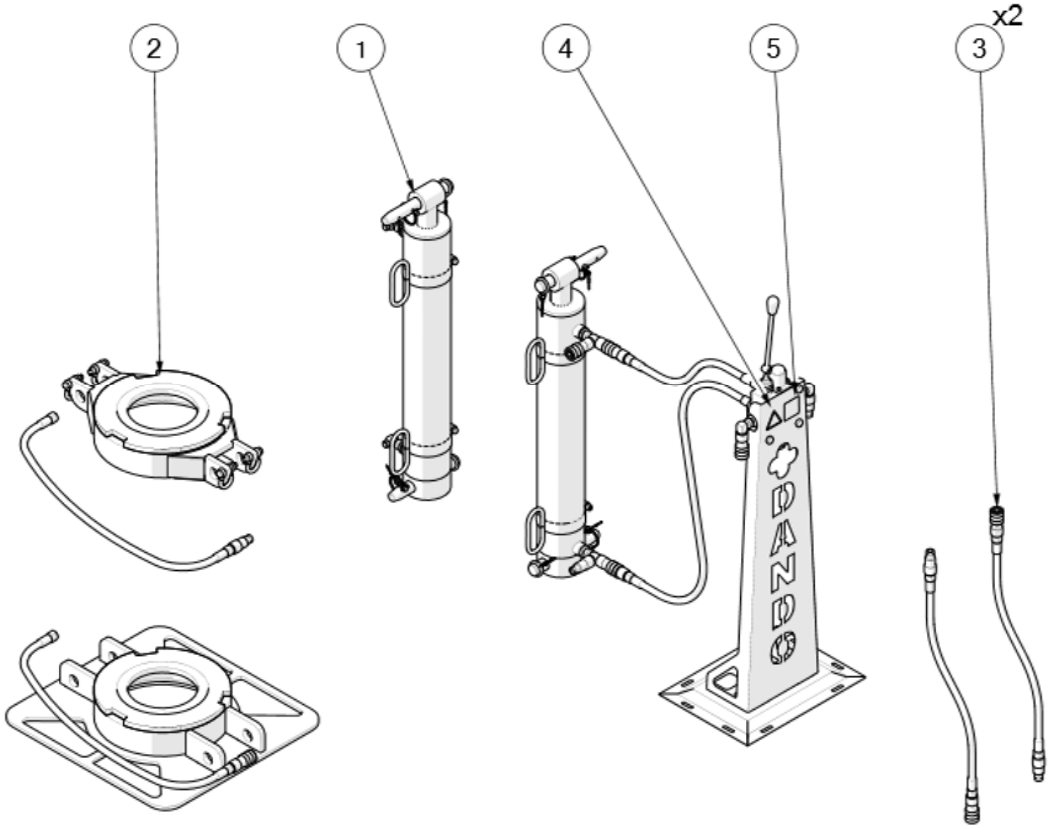
200108355 CLAMP BRACKET ASSEMBLY - SPREADER BAR



200108355 CLAMP BRACKET ASSEMBLY - SPREADER BAR

BOM ID	Number	Description	Qty
1	200105901	MODS TO CATCH PLATE	1
2	200108347	CLAMP BRACKET FABRICATION (SPREADER BAR)	1
3	200108352	LOCKING PLATE - SPREADER BAR	1
4	900100259	V TYPE RUBBER ROLLER 90mm LG x 11mm BORE [INDESPENSION - NA001]	1
5	C10000942	M5 SOCKET BUTTON HEADCAP SCREW X 16 LONG [ZINC PLATED]	2
6	C102C01616	TOGGLE LATCH - HEAVY DUTY PADLOCKABLE	1
7	ST01109X510	M10 NYLOC NUT	2
8	ST01176X881	M8 PLAIN WASHER	2
9	v2ST04379X510	M8 NYLOC NUT	2
10	ST04814X133	M8 HEX HEAD SET SCREW x 25 LG.	2
11	ST05092X133	M10 HEX HD BOLT HT x 130 LONG	1
12	ST10053X133	M10 HEX HD BOLT HT x 50 LONG	1
13	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	3

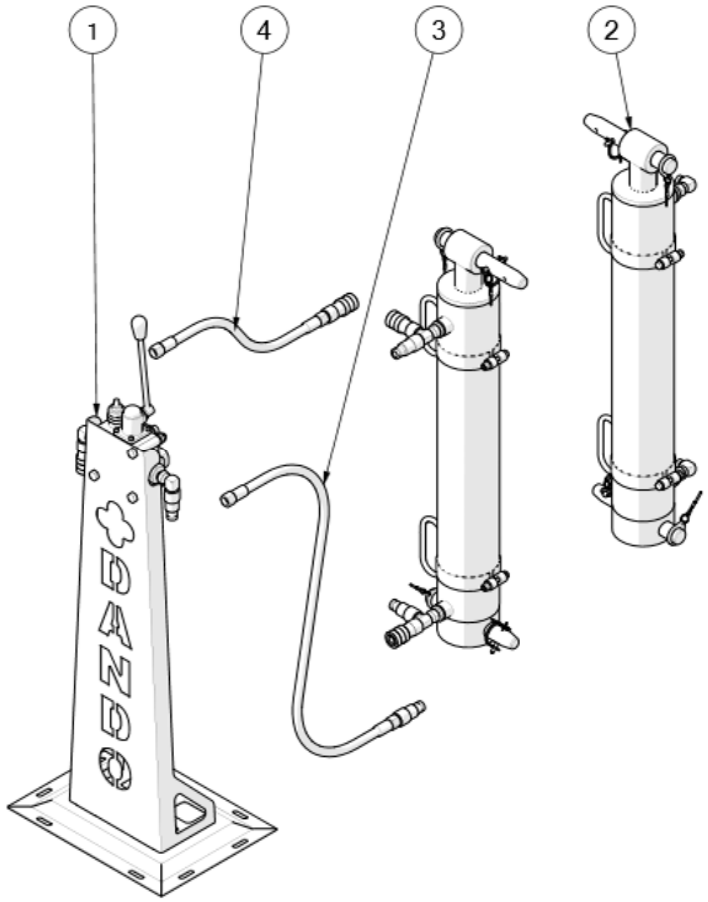
200109000 CASING JACK ASSEMBLY [MEDIUM]



200109000 CASING JACK ASSEMBLY [MEDIUM]

BOM ID	Number	Description	Qty
1	200109101	CONSOLE & RAM ASSY [CASING JACK]	1
2	200109102	CASING JACK KIT [MEDIUM]	1
3	200109126	HOSE ASSY 0.375IN 3M LG [0.375 MALE QR TO 0.375 FEMALE QR]	2
4	910100247	GENERAL WARNING DECAL (2 INCH)	1
5	910100262	REFER TO INSTRUCTIONS DECAL (50MM)	1

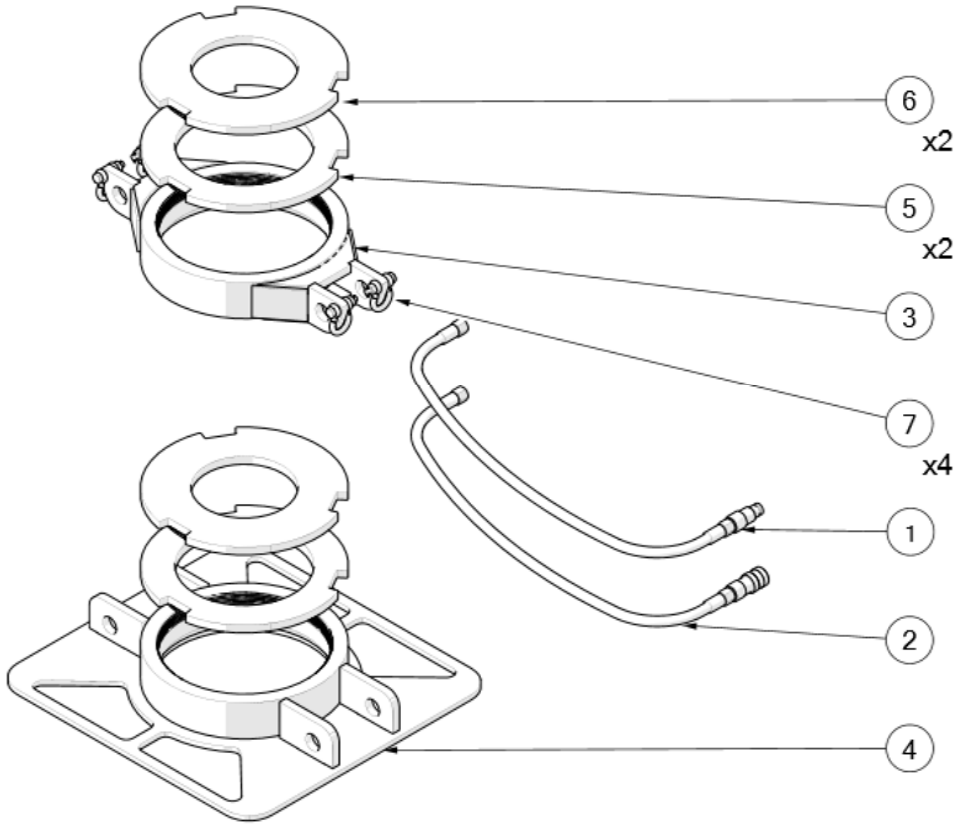
200109101 CONSOLE & RAM ASSEMBLY [CASING JACK]



200109101 CONSOLE & RAM ASSEMBLY [CASING JACK]

BOM ID	Number	Description	Qty
1	200108319	CONSOLE ASSY [CASING JACK]	1
2	200109103	RAM ASSY	1
3	200109108	HOSE ASSY 0.375IN 3M LG [0.375 MALE QR TO 0.375 FEMALE BSPP]	1
4	200109109	HOSE ASSY 0.375IN 3M LG [0.375 FEMALE QR TO 0.375 FEMALE BSPP]	1

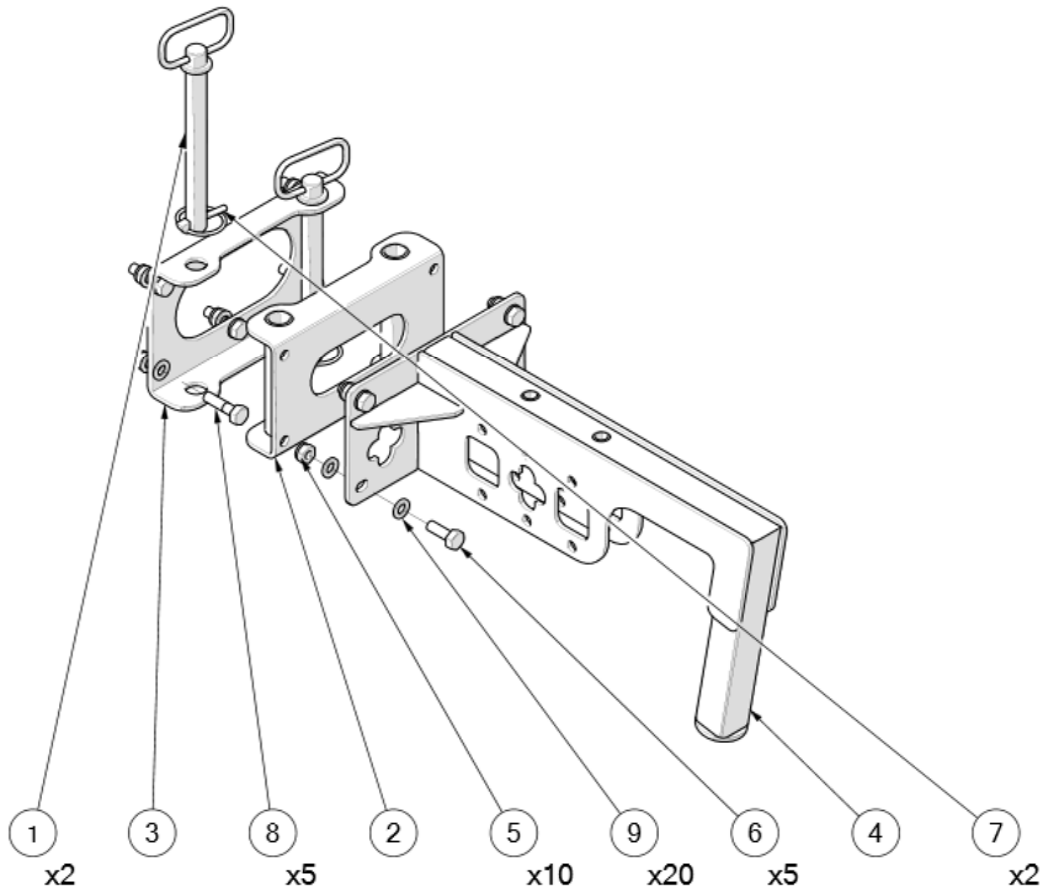
200109102 CASING JACK KIT [MEDIUM]



200109102 CASING JACK KIT [MEDIUM]

BOM ID	Number	Description	Qty
1	200109111	HOSE ASSY 0.375IN 0.9M LG [0.375 MALE QR TO 0.375 FEMALE BSPP]	1
2	200109112	HOSE ASSY 0.375IN 0.9M LG [0.375 FEMALE QR TO 0.375 FEMALE BSPP]	1
3	200109113	UPPER CASING JACK FAB [MEDIUM]	1
4	200109114	LOWER CASING JACK FAB [MEDIUM]	1
5	200109115	6IN BUSH [MACHINED]	2
6	200109116	8IN BUSH [MACHINED]	2
7	910102219	1T BOLT TYPE ANCHOR SHACKLE [CROSBY 1019470]	4

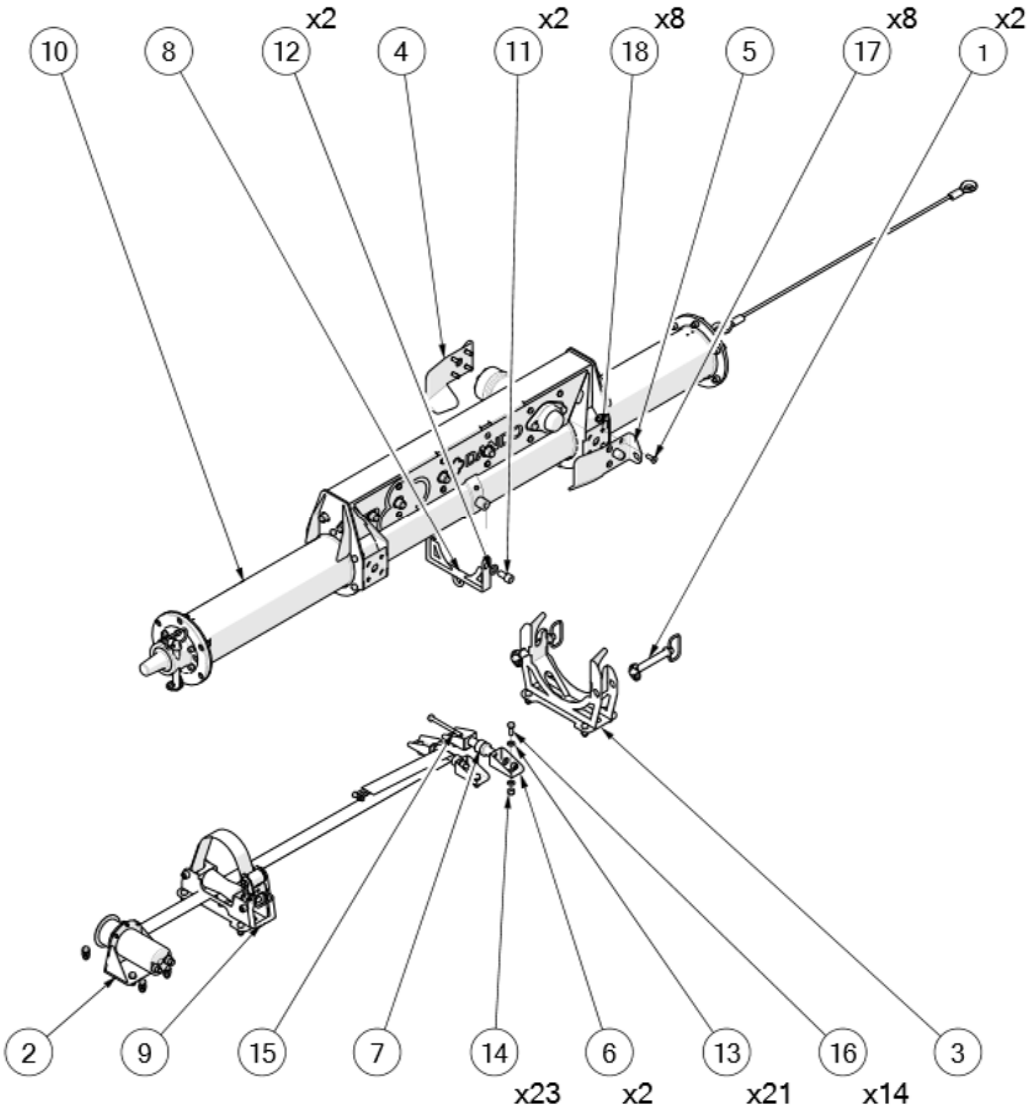
200108315 CORE EXTRACTOR ASSEMBLY



200108315 CORE EXTRACTOR ASSEMBLY

BOM ID	Number	Description	Qty
1	200101120	20 DIA HITCH PIN (ZPTP20)	2
2	200101708	MOUNTING BRACKET FABRICATION - CORE EXTRACTOR	1
3	200101711	MOUNTING BRACKET - SPREADER BAR	1
4	200108314	CORE EXTRACTOR FABRICATION	1
5	ST01109X510	M10 NYLOC NUT	10
6	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	5
7	ST09816X666	6 DIA LINCH PIN	2
8	ST10370X133	M10 HEX HEAD BOLT HT x 40 LONG	5
9	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	20

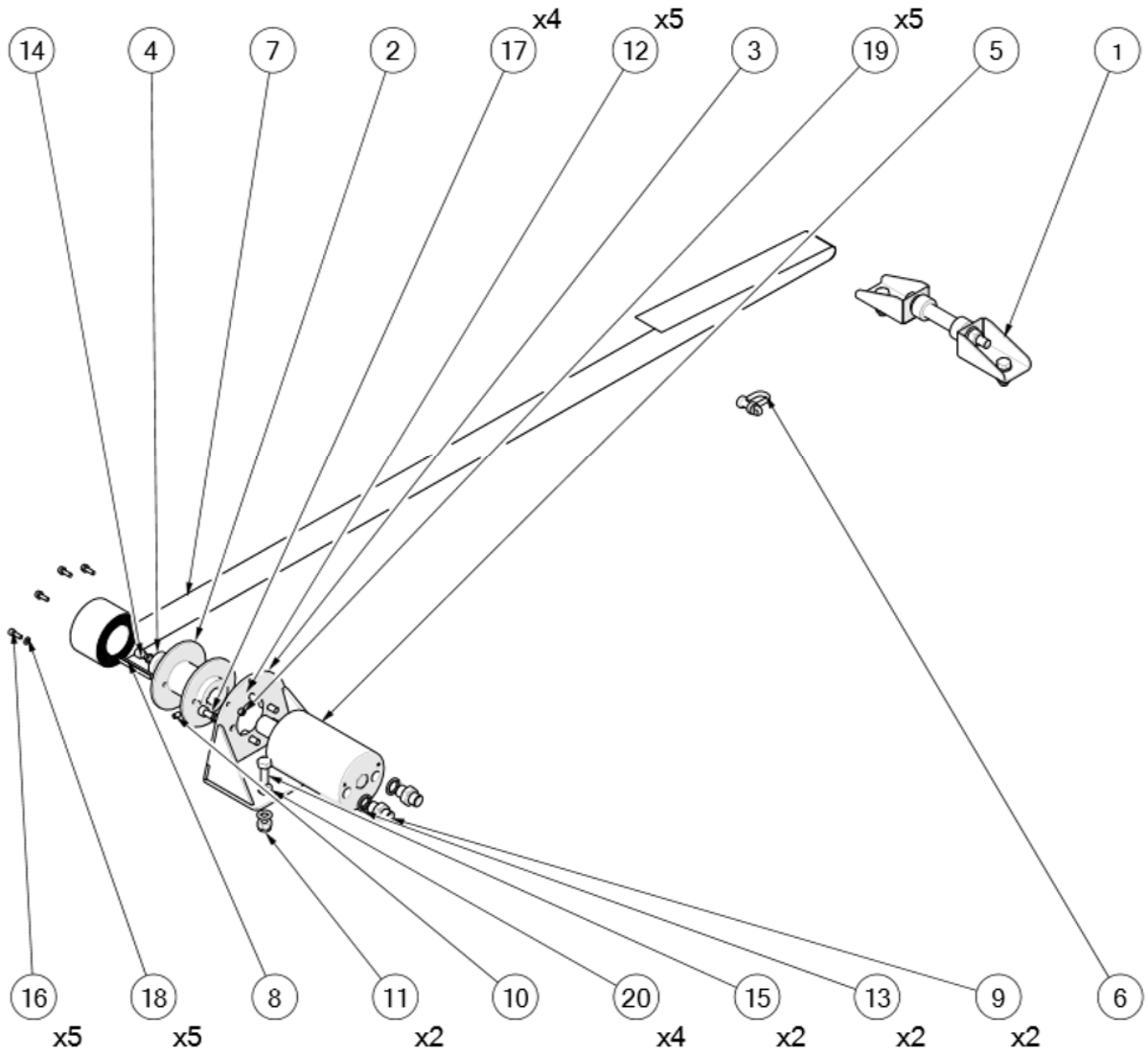
200105970 STOWAGE ASSEMBLY (MULTI-HEIGHT SPT HAMMER)



200105970 STOWAGE ASSEMBLY (MULTI-HEIGHT SPT HAMMER)

BOM ID	Number	Description	Qty
1	200101121	20 DIA HITCH PIN 145 LG, CW LINCH PIN & CHAIN	2
2	200106333	SPT STOWING WINCH ASSY	1
3	200106336	TOP STOWAGE BRACKET FABRICATION (SPT HAMMER)	1
4	200106341	LOCKING BRACKET FABRICATION LH	1
5	200106343	LOCKING BRACKET FABRICATION RH	1
6	200106345	ROLLER BRACKET	2
7	200106346	ROLLER - 5MM WIRE ROPE	1
8	200106352	WIRE ROPE BRACKET FAB	1
9	200106358	BOTTOM STOWAGE BRACKET ASSEMBLY (SPT HAMMER)	1
10	200106815	MULTI-HEIGHT SPT HAMMER ASSY	1
11	ST00596X743	M16 SOCKET HEAD CAP SCREW x 30 LONG	2
12	ST00656X881	M16 ORDINARY WASHER	2
13	ST01048X881	M10 PLAIN WASHER	21
14	ST01109X510	M10 NYLOC NUT	23
15	ST02142X133	M10 HEX HD SET SCREW HT x 120 LONG	1
16	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	14
17	ST11009X763	M10 SOC HEAD C/SK SCREW x 30 LONG	8
18	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	8

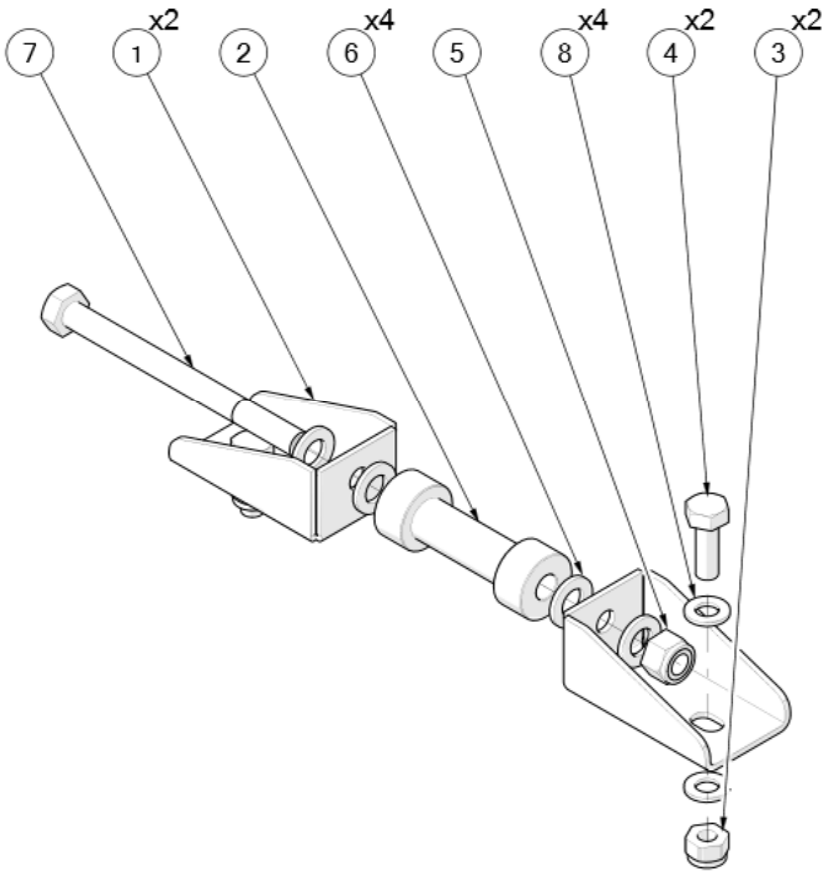
200106333 SPT STOWING WINCH ASSEMBLY



200106333 SPT STOWING WINCH ASSEMBLY

BOM ID	Number	Description	Qty
1	200115329	STRAP GUIDE ASSEMBLY (SPT)	1
2	200800517	SPT STOWAGE WINCH STRAP - DRUM	1
3	200800522	SPT STOWAGE WINCH MOTOR MOUNT FAB	1
4	200800528	SPT STOWAGE WINCH DRUM RETAINING SPIGOT	1
5	700200230	HYDRAULIC MOTOR HIGH TOQURE LOW SPEED 40CC/REV	1
6	900100185	D SHACKLE 0.25TON	1
7	900101115	WINCH STRAP 4M x 50MM 2,000KG CAPACITY CW HOOK, RETAINING PIN AND CERTIFICATE	1
8	910200309	ROLL PIN 8 DIA X 60 LG	1
9	ST00168X326	3/8" BSP MALE/MALE STUD ADAPTOR	2
10	ST00778X747	M6 SOCKET SET SCREW [GRUB] x 10 LONG	1
11	ST01109X510	M10 NYLOC NUT	2
12	ST01146X885	M8 SPRING WASHER SINGLE COIL	5
13	ST01156X328	3/8"BSP BONDED SEAL [DOWTY]	2
14	ST02630X743	M8 SOCKET HEAD CAPSCREW x 30 LONG	1
15	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	2
16	ST06149X743	M5 SOCKET HEAD CAP SCREW x 15 LG	5
17	ST06590X743	M8 SOCKET HEAD CAP SCREW x 20 LG	4
18	ST09754X883	M5 PLAIN WASHER - BRIGHT	5
19	ST09755X510	M5 NYLOC NUT	5
20	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	4

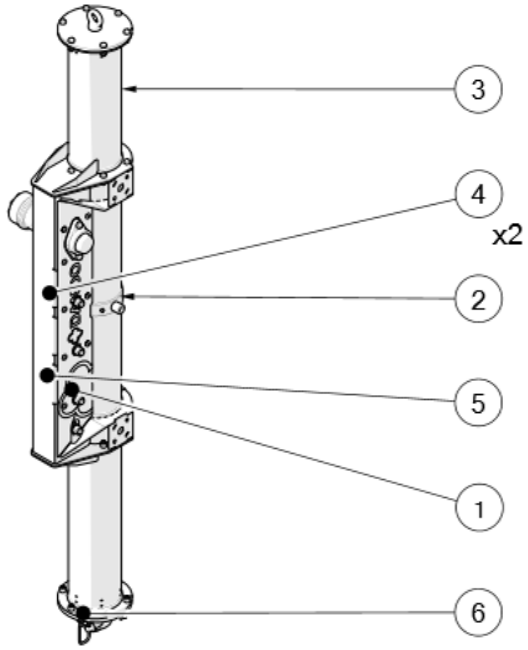
200115329 STRAP GUIDE ASSEMBLY (SPT)



200115329 STRAP GUIDE ASSEMBLY (SPT)

BOM ID	Number	Description	Qty
1	200106345	ROLLER BRACKET	2
2	200115327	ROLLER GUIDE (SPT)	1
3	ST01109X510	M10 NYLOC NUT	2
4	ST05367X715	M10 HEX HEAD SET SCREW HT x 30 LG	2
5	ST06828X523	M12 NYLOC NUT	1
6	ST09900X883	M12 PLAIN BRIGHT WASHER	4
7	ST10158X133	M12 HEX. HEAD BOLT HT x 140 LG	1
8	ST11180X511	M10 NB ORDINARY WASHER (ZINC PLATED)	4

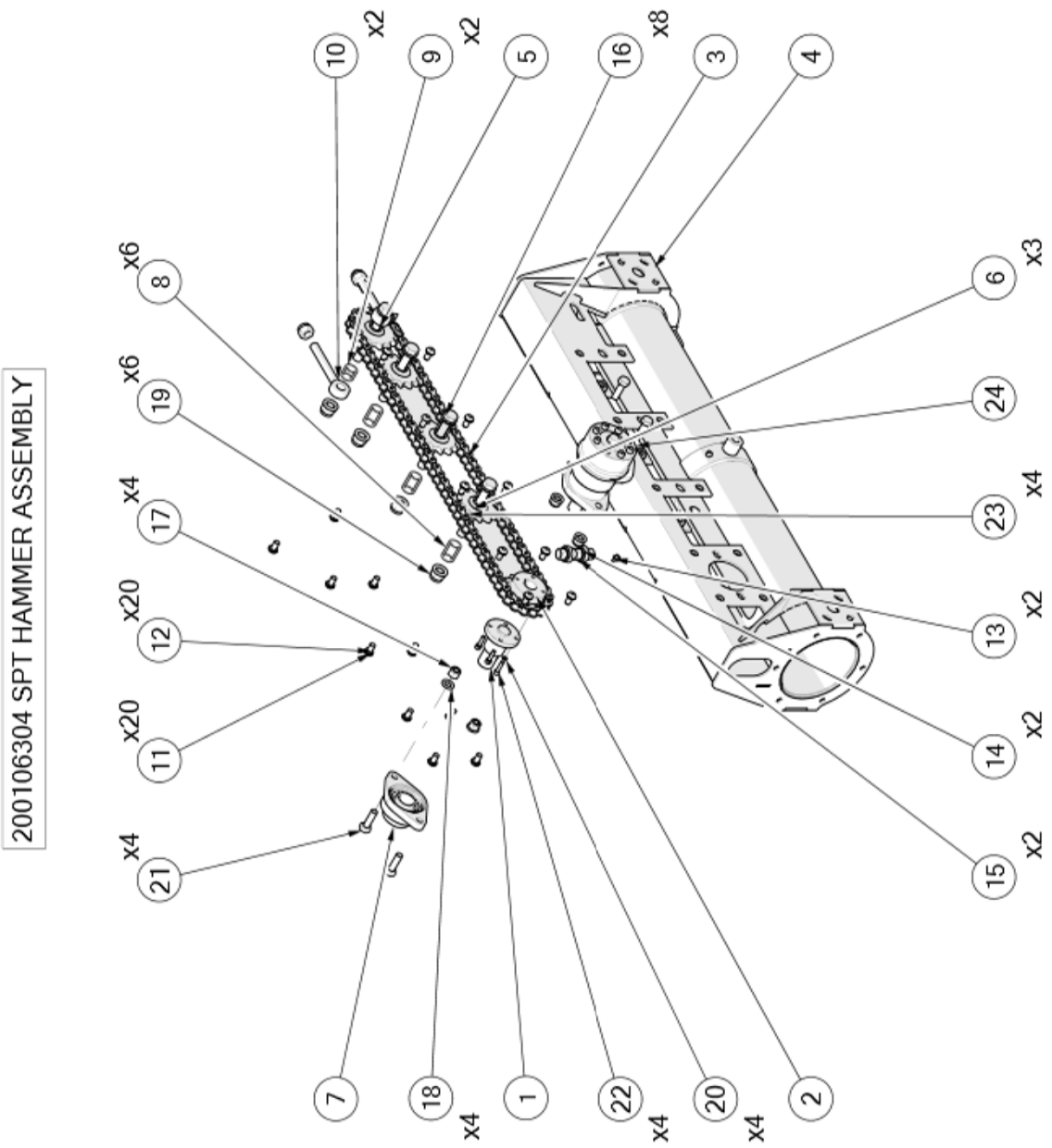
200106815 MULTI-HEIGHT SPT HAMMER ASSEMBLY



200106815 MULTI-HEIGHT SPT HAMMER ASSEMBLY

BOM ID	Number	Description	Qty
1	200105898	LIVERY - SPT CARRIAGE (MULTIHEIGHT)	1
2	200106304	SPT HAMMER ASSY [CORE]	1
3	200106816	MULTI-HEIGHT SPT KIT	1
4	200106877	DANDO LETTERING (SPT) (SILVER)	2
5	200106889	SILVER QUATREFOIL RH (TERRIER SPT HAMMER)	1
6	910100248	HAND CRUSH DECAL (2 INCH)	1

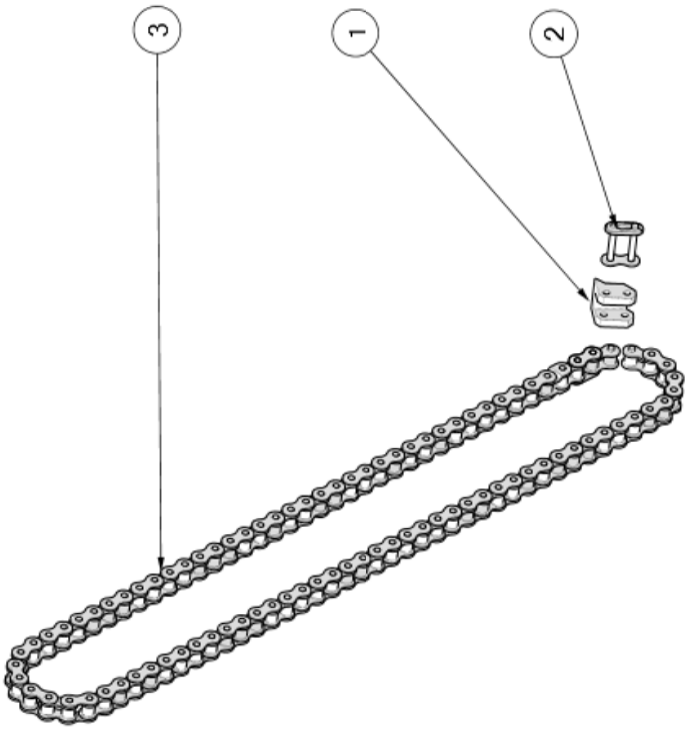
200106304 SPT HAMMER ASSEMBLY



200106304 SPT HAMMER ASSEMBLY

BOM ID	Number	Description	Qty
1	200105884	ALIGNMENT SHAFT	1
2	200105885	MOTOR SPROCKET [WITH SHAFT]	1
3	2001066021	DRIVE CHAIN ASSY	1
4	200106039	SPT CARRIAGE FAB	1
5	200106201	IDLER SPROCKET FOR 3/4" PITCH 12B1 CHAIN 15 TOOTH 16MM BORE	1
6	200106204	IDLER SPROCKET FOR 3/4" PITCH 12B1 CHAIN 13 TOOTH 16MM BORE	3
7	910100283	30MM Y-BEARING OVAL FLANGE UNIT	1
8	910100313	25 X 16.5 X 35 NYLON SPACER	6
9	910100314	25 X 16.5 X 20 NYLON SPACER	2
10	910100315	M16 X 100LG GATE EYE BOLT CW 2 OFF NUTS	2
11	C100G00911	M10 S.S. HEX SOC BUTTON HEAD SCREW X 20 LG	20
12	C100G01145	M10 x 16.5 OD NORD-LOCK WASHER	20
13	ST00180X270	1/8" BSP STR GREASE NIPPLE	2
14	ST00245X326	1/2" BSP MALE/MALE STUD ADAPTOR	2
15	ST00246X328	1/2" BSP BONDED SEAL	2
16	ST00656X881	M16 ORDINARY WASHER	8
17	ST00787X510	M12 NYLOC NUT	4
18	ST00788X881	M12 PLAIN WASHER	4
19	ST00934X510	M16 NYLOC NUT	6
20	ST01179X885	M6 SPRING WASHER	4
21	ST04885X715	M12 SET SCREW HEX HD HT x 40 LONG	4
22	ST07265X743	M6 SOCKET CAP SCREW X 25 LG	4
23	ST08530X133	M16 HEX HD BOLT HT x 130 LONG	4
24	ST10373X475	HYD. MOTOR - AWMP 75 MX (ADAN)	1

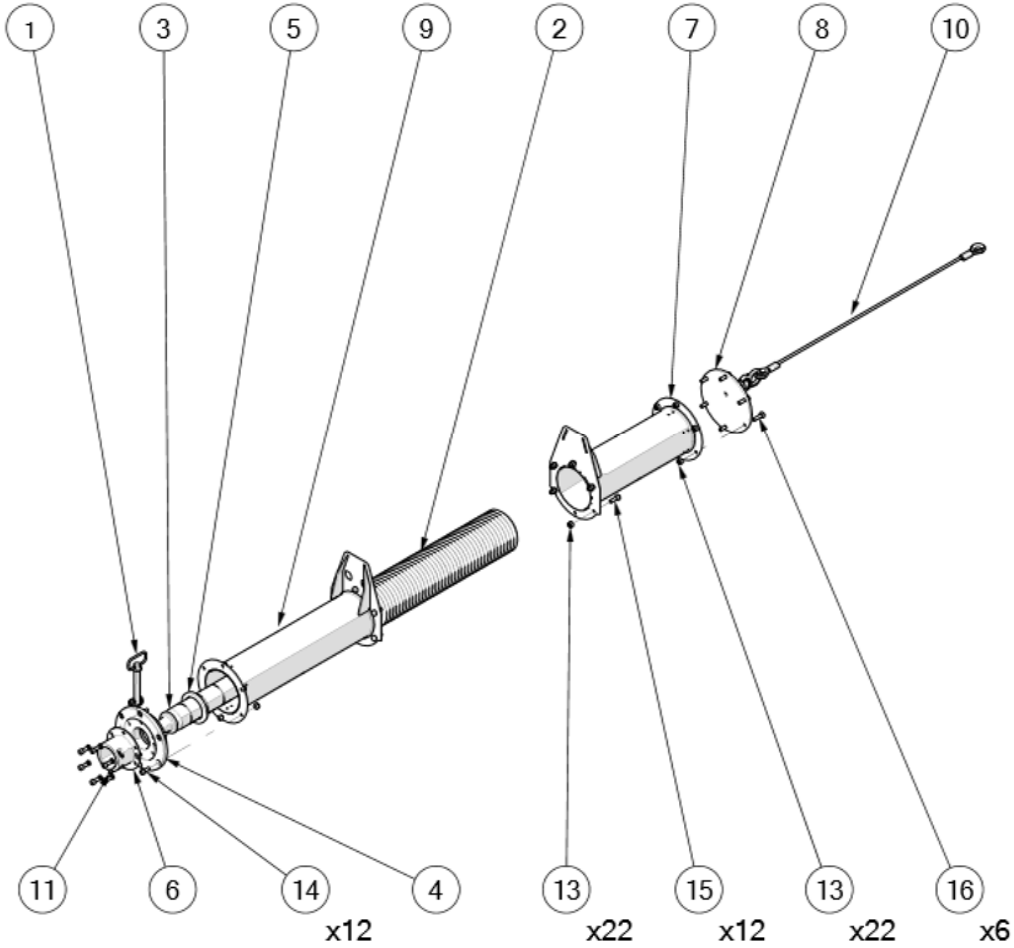
200106021 DRIVE CHAIN ASSEMBLY



200106021 DRIVE CHAIN ASSEMBLY

BOM ID	Number	Description	Qty
1	200106022	CAM BODY	1
2	910100284	DUPLEX 0.75IN CONNECTING LINK & SPRING CLIP	1
3	ST11173X161	DRIVE CHAIN ASSY	1

200106816 MULTI-HEIGHT SPT KIT

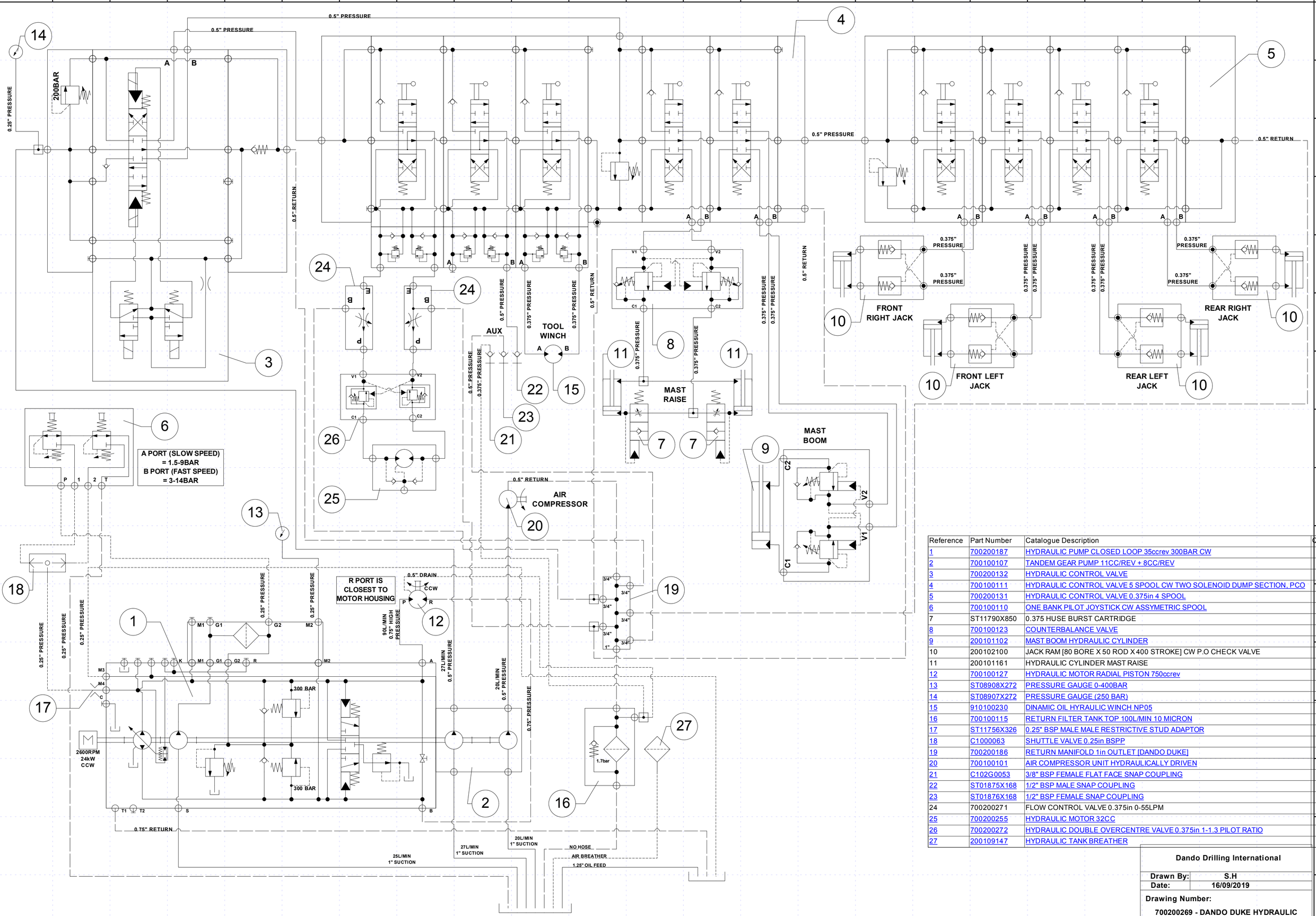


200106816 MULTI-HEIGHT SPT KIT

BOM ID	Number	Description	Qty
1	200101121	20 DIA HITCH PIN 145 LG, CW LINCH PIN & CHAIN	1
2	200106011	WEIGHT BODY (63.5KG MULTI-HEIGHT)	1
3	200106640	MULTI-HEIGHT DRIVE ANVIL [CONED MALE]	1
4	200106701	ANVIL GUIDE	1
5	200106703	ANVIL GUIDE RUBBER RING	1
6	200106813	ANVIL GUIDE [MULTI-HEIGHT]	1
7	200106817	WEIGHT HOUSING [TOP - MULTI-HEIGHT]	1
8	200106819	TOP CAP	1
9	200106821	WEIGHT HOUSING [BOTTOM - MULTI-HEIGHT]	1
10	910100373	0.99T WIRELINE SLING ASSY	1
11	ST00180X270	1/8" BSP STR GREASE NIPPLE	1
12	ST00777X885	M10 SINGLE COIL SPRING WASHER	9
13	ST01109X510	M10 NYLOC NUT	22
14	ST01393X743	M10 SOC HD CAP SCREW x 25 LONG	12
15	ST07305X133	M10 HEX HEAD BOLT HT x 30 LONG	12
16	ST09086X715	M10 HEX HEAD SET SCREW HT x 35 LG.	6

SECTION 6

HYDRAULIC CIRCUIT



Reference	Part Number	Catalogue Description	Quantity
1	700200187	HYDRAULIC PUMP CLOSED LOOP 35ccrev 300BAR CW	1
2	700100107	TANDEM GEAR PUMP 11CC/REV + 8CC/REV	1
3	700200132	HYDRAULIC CONTROL VALVE	1
4	700100111	HYDRAULIC CONTROL VALVE 5 SPOOL CW TWO SOLENOID DUMP SECTION, PCO	1
5	700200131	HYDRAULIC CONTROL VALVE 0.375in 4 SPOOL	1
6	700100110	ONE BANK PILOT JOYSTICK CW ASSYMETRIC SPOOL	1
7	ST11790X850	0.375 HUSE BURST CARTRIDGE	2
8	700100123	COUNTERBALANCE VALVE	1
9	200101102	MAST BOOM HYDRAULIC CYLINDER	1
10	200102100	JACK RAM [80 BORE X 50 ROD X 400 STROKE] CW P.O CHECK VALVE	4
11	200101161	HYDRAULIC CYLINDER MAST RAISE	2
12	700100127	HYDRAULIC MOTOR RADIAL PISTON 750ccrev	1
13	ST08908X272	PRESSURE GAUGE 0-400BAR	1
14	ST08907X272	PRESSURE GAUGE (250 BAR)	1
15	910100230	DINAMIC OIL HYRAULIC WINCH NP05	1
16	700100115	RETURN FILTER TANK TOP 100L/MIN 10 MICRON	1
17	ST11756X326	0.25" BSP MALE MALE RESTRICTIVE STUD ADAPTOR	1
18	C1000063	SHUTTLE VALVE 0.25in BSPP	1
19	700200186	RETURN MANIFOLD 1in OUTLET [DANDO DUKE]	1
20	700100101	AIR COMPRESSOR UNIT HYDRAULICALLY DRIVEN	1
21	C102G0053	3/8" BSP FEMALE FLAT FACE SNAP COUPLING	1
22	ST01875X168	1/2" BSP MALE SNAP COUPLING	1
23	ST01876X168	1/2" BSP FEMALE SNAP COUPLING	1
24	700200271	FLOW CONTROL VALVE 0.375in 0-55LPM	2
25	700200255	HYDRAULIC MOTOR 32CC	1
26	700200272	HYDRAULIC DOUBLE OVERCENTRE VALVE 0.375in 1-1.3 PILOT RATIO	1
27	200109147	HYDRAULIC TANK BREATHER	1

Dando Drilling International

Drawn By:	S.H
Date:	16/09/2019

Drawing Number:

700200269 - DANDO DUKE HYDRAULIC CIRCUIT STAGE 4 ENGINE CW SPT WINCH

SECTION 7

ELECTRICAL CIRCUITS

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
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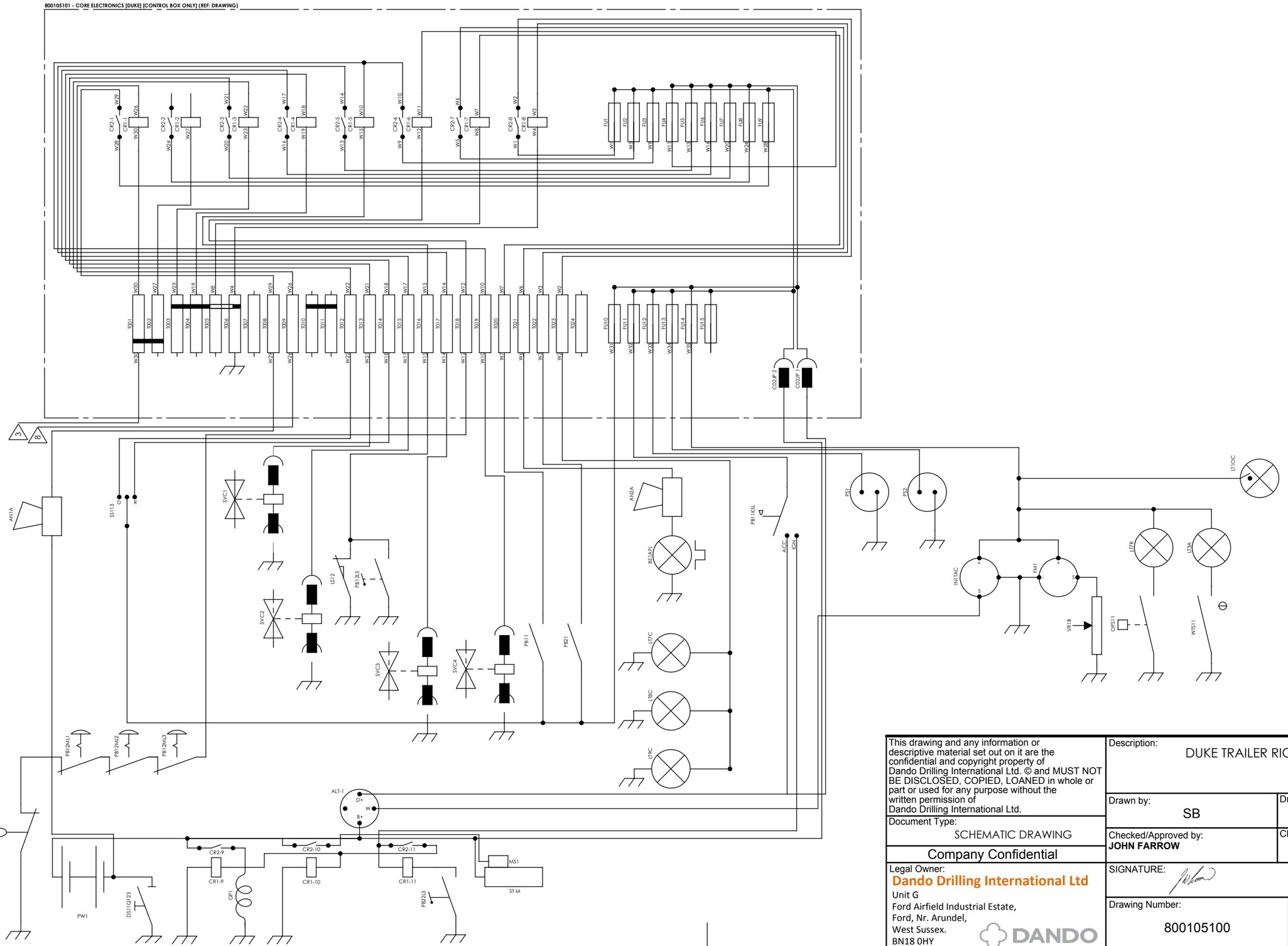
-	-	-	-
-	-	-	-

800105101 - CORE ELECTRONICS [DUKE] [CONTROL BOX ONLY] (REF: DRAWING)



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Document Type: SCHEMATIC DRAWING	Drawn by: SB / Drawn Date: 10/09/2019
Company Confidential	Checked/Approved by: JOHN FARROW / Checked/Approved Date: 17/09/2019
Legal Owner: Dando Drilling International Ltd Unit G Ford Airfield Industrial Estate, Ford, Nr. Arundel, West Sussex. BN18 0HY	SIGNATURE:
	Drawing Number: 800105100 / Sheet Size: A3 / Sheet: 1 of 9 / Revision: A

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
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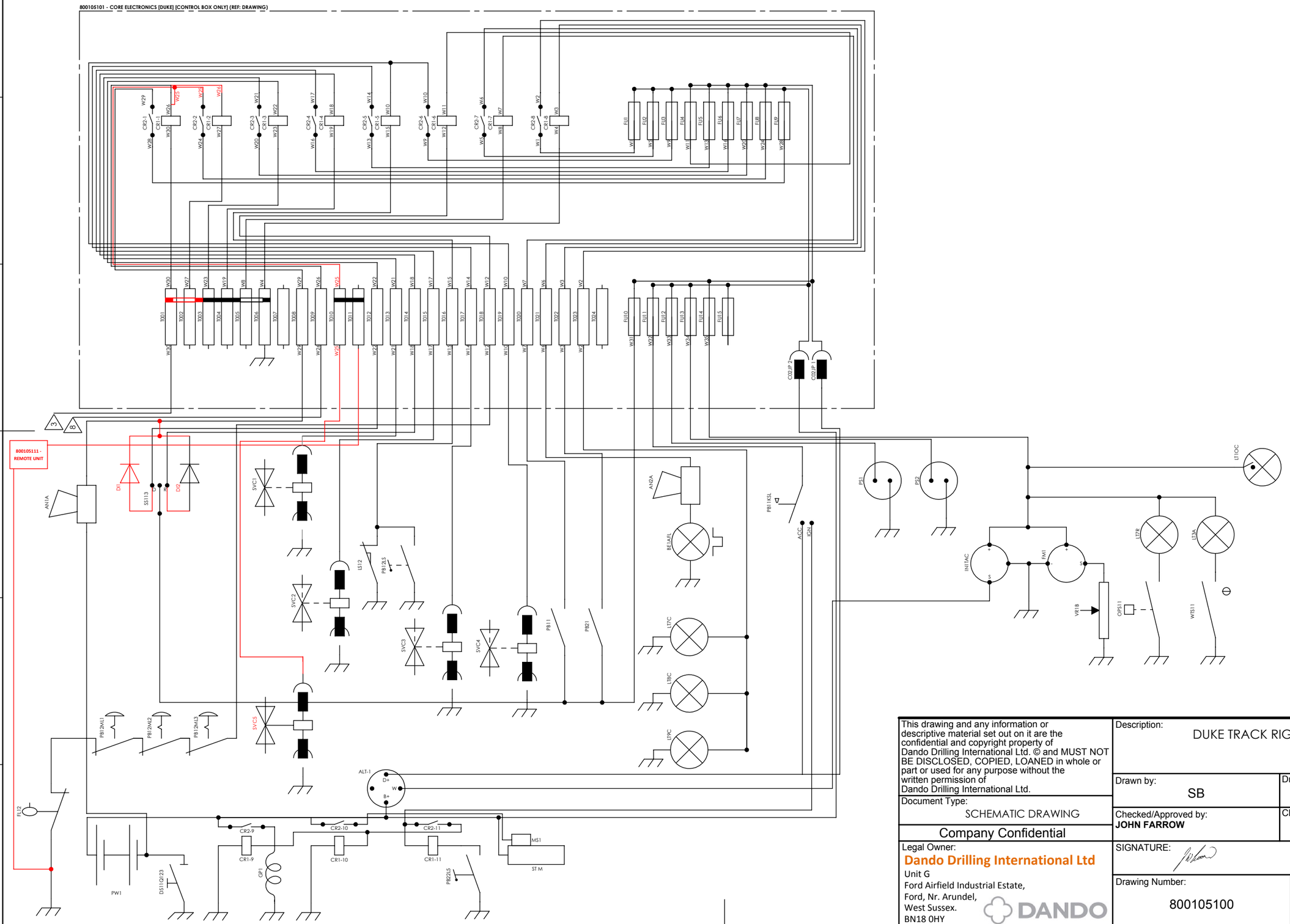
-	-	-	-
-	-	-	-

800105101 - CORE ELECTRONICS [DUKE] [CONTROL BOX ONLY] (REF: DRAWING)

800105111 - REMOTE UNIT



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Document Type: SCHEMATIC DRAWING	Drawn by: SB	Drawn Date: 10/09/2019	
Company Confidential	Checked/Approved by: JOHN FARROW	Checked/Approved Date: 17/09/2019	
Legal Owner: Dando Drilling International Ltd Unit G Ford Airfield Industrial Estate, Ford, Nr. Arundel, West Sussex. BN18 0HY	SIGNATURE:		
	Drawing Number: 800105100	Sheet Size: A3	Sheet: 2 of 9 / Revision: A

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
-	-	-	-
-	-	-	-
-	-	-	-

ITEM	DISCRIPTION	ITEM	DISCRIPTION	ITEM	DISCRIPTION
PW1	12V BATTERY	PB12ML3	E-STOP	DI1	TRACK DIODE
C02JP1	POWER FROM IGN. SWITCH	DS11Q123	BATTERY ISOLATOR	DI2	TRACK DIODE
C02JP2	POWER FROM BATTERY	PB11	HORN & BEACON SWITCH	SVC5	TRACK SOLENOID
PS1	12V SOCKET	PB21	RIG LIGHT SWITCH		
PS2	CIGARETTE LIGHTER SOCKET	OPS11	OIL PRESSURE SWITCH		
LT7C	RIG LIGHT	WTS11	WATER TEMPERATURE SWITCH		
LT8C	RIG LIGHT	SVC1	DRILLING SOLENOID		
LT9C	RIG LIGHT	SVC2	RIGING SOLENOID		
LT10C	PANEL LIGHT	SVC3	BRAKE SOLENOID		
LT7R	OIL PRESSURE WARNING LIGHT	SVC4	FUEL SOLENOID		
LT3A	WATER TEMPERATURE WARNING LIGHT	CR1-9	GLOW PLUG RELAY COIL		
AN1A	REVERSING/TRACKING ALARM	CR2-9	GLOW PLUG RELAY CONTACT		
AN2A	HORN	CR1-10	STARTER RELAY COIL		
BE1AFL	FLASHING ORANGE HORN BEACON	CR2-10	STARTER RELAY CONTACT		
SS113	DRILLING & RIGING SELECTOR SWITCH	CR1-11	STARTER/BRAKE INTERLOCK RELAY COIL		
PB11KSL	IGNITION KEY SWITCH	CR2-11	STARTER/BRAKE INTERLOCK RELAY CONTACT		
PB12LS	LIMIT SWITCH LEVER OVERIDE	GP1	GLOW PLUG		
PB22LS	START/SPEED MOTOR CONTROL SWITCH	MS1	STARTER COIL		
FL12	E-STOP FLOAT LEVEL SWITCH SWITCH	ALT 1	ALERNATOR		
LS12	MAST LIMIT SWITCH	IN1TAC	TACHOMETER		
PB12ML1	E-STOP	FM1	FUEL LEVEL METER		
PB12ML2	E-STOP	VR1B	FUEL LEVEL SENSOR		

EXPENDABLE PARTS

ITEM	DISCRIPTION	PART No.	ITEM	DISCRIPTION	PART No.
FU1	RIG LIGHT FUSE [10 AMP]	800100132	CR1-1	REVERSE ALARM RELAY COIL	800100230
FU2	HORN FUSE [10 AMP]	800100132	CR2-1	REVERSE ALARM RELAY CONTACT	
FU3	FUEL SOLENOID [10 AMP]	800100132	CR1-2	TRACKING RELAY COIL	800100230
FU4	E-STOP SOLENOID FUSE [10 AMP]	800100132	CR2-2	TRACKING RELAY CONTACT	
FU5	BRAKE SOLENOID FUSE [5 AMP]	800100131	CR1-3	DRILLING SOLENOID RELAY COIL	800100230
FU6	RIGGING SOLENOID FUSE [5 AMP]	800100131	CR2-3	DRILLING SOLENOID RELAY CONTACT	
FU7	DRILLING SOLENOID FUSE [5AMP]	800100131	CR1-4	RIGGING SOLENOID RELAY COIL	800100230
FU8	TRACKING FUSE [10 AMP]	800100132	CR2-4	RIGGING SOLENOID RELAY CONTACT	
FU9	REVERSE ALARM FUSE [10 AMP]	800100132	CR1-5	BRAKE SOLENOID RELAY COIL	800100230
FU10	SWITCHES FUSE [5 AMP]	800100131	CR2-5	BRAKE SOLENOID RELAY CONTACT	
FU11	IGN. SWITCH FUSE [15 AMP]	800100182	CR1-6	FUEL SOLENOID RELAY COIL	800100230
FU12	12V SOCKET FUSE [10 AMP]	800100132	CR2-6	FUEL SOLENOID RELAY CONTACT	
FU13	CIGARETTE LIGHTER FUSE [10 AMP]	800100132	CR1-7	HORN RELAY COIL	800100230
FU14	INSTRUMENT SUPPLY FUSE [10 AMP]	800100132	CR2-7	HORN RELAY CONTACT	
FU15	SPARE FUSE		CR1-8	RIG LIGTHS RELAY COIL	800100230
			CR2-8	RIG LIGTHS RELAY CONTACT	

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DANDO

Description: DUKE SCHEMATIC INFORMATION

Drawn by:	Drawn Date:
SB	10/09/2019
Checked/Approved by: JOHN FARROW	Checked/Approved Date: 17/09/2019

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Drawing Number:	Sheet Size:	Sheet:	Revision:
800105100	A3	3 of 9	A

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REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
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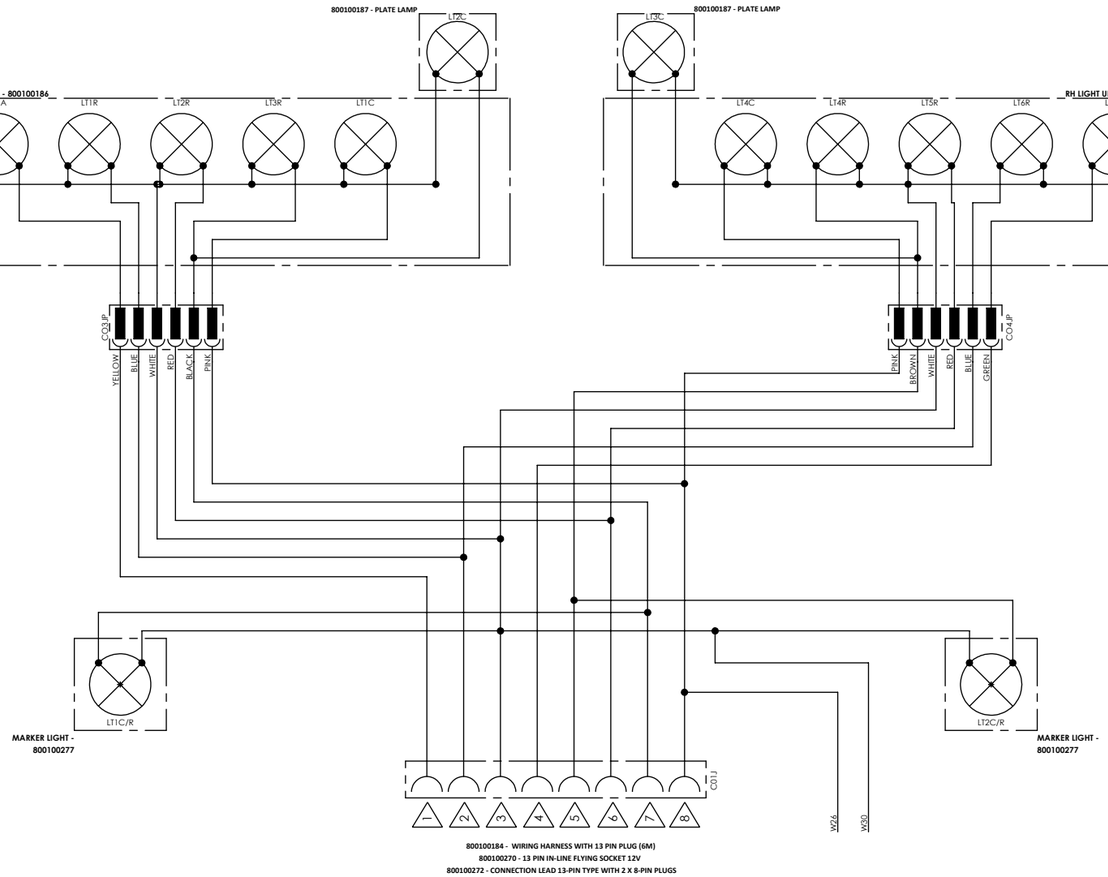
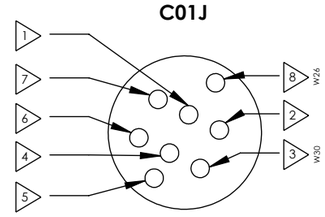
-	-	-	-
-	-	-	-



ITEM	DISCRIPTION
C01J	13-PIN FEMALE PLUG
CO3JP	LEFT HAND LIGHT UNIT PLUG
CO4JP	RIGHT HAND LIGHT UNIT PLUG
LT1C/R	LEFT HAND MARKER LIGHT
LT2C/R	RIGHT HAND MARKER LIGHT

ITEM	DISCRIPTION
LT1A	INDICATOR LIGHT BULB
LT1R	FOG LIGHT BULB
LT2R	BRAKE LIGHT BULB
LT3R	SIDE LIGHT, LIGHT BULB
LT1C	REVERSE LIGHT BULB
LT2C	NO. PLATE LIGHT BULB
LT3C	NO. PLATE LIGHT BULB
LT4C	REVERSE LIGHT BULB
LT4R	SIDE LIGHT, LIGHT BULB
LT5R	BRAKE LIGHT BULB
LT6R	FOG LIGHT BULB
LT2A	INDICATOR LIGHT BULB

C01J



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Description: DUKE TRAILER LIGHTS SCHEMATIC

Drawn by:	Drawn Date:
SB	10/09/2019
Checked/Approved by: **JOHN FARROW**	Checked/Approved Date: 17/09/2019

SIGNATURE:

Drawing Number:	Sheet Size:	Sheet:	Revision:
800105100	A3	4 of 9	**A**

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
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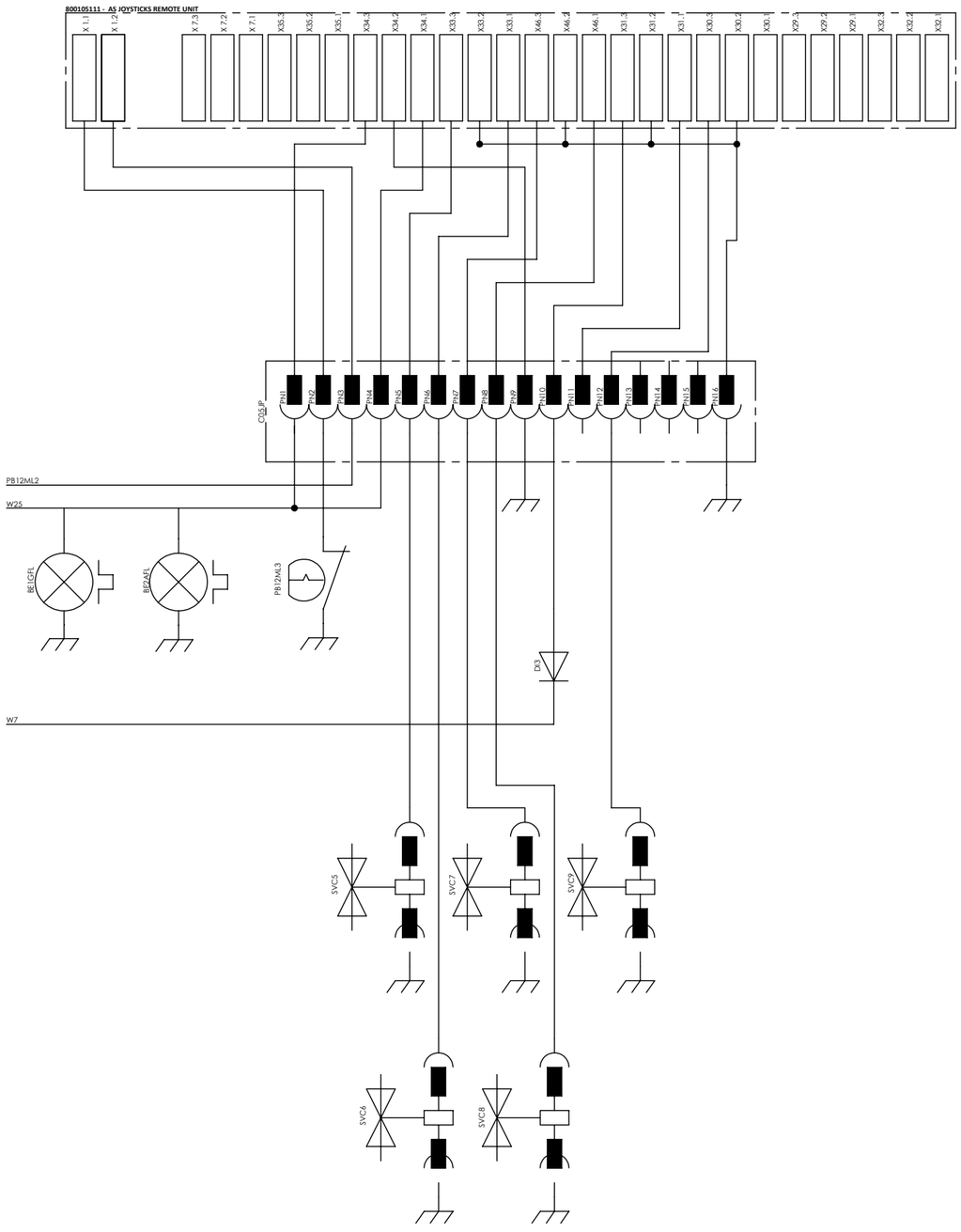
-	-	-	-



ITEM	DISCRIPTION
CO5JP	PEMOTE 16 WAY PLUG & SOCKET
BE1GFL	GREEN TRACK LIGHT
BE2GFL	GREEN TRACK LIGHT
PB12ML3	E - STOP
D13	HORN DIODE
SVC5	CRAWLER TRACK LEFT FORWARD
SVC6	CRAWLER TRACK LEFT BACKWARD
SVC7	CRAWLER TRACK RIGHT FORWARD
SVC8	CRAWLER TRACK RIGHT BACKWARD
SVC9	SPEED CONTROLL SOLENOID

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Description: DUKE TRACK RADIO REMOTE SCHEMATIC

Drawn by:	Drawn Date:
SB	10/09/2019
Checked/Approved by: JOHN FARROW	Checked/Approved Date: 17/09/2019

SIGNATURE:

Drawing Number:	Sheet Size:	Sheet:	Revision:
800105100	A3	5 of 9	A

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REVISION	DESCRIPTION	DATE	INITIALS
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-	-	-	-
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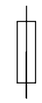
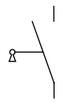
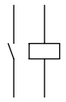
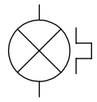
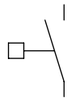
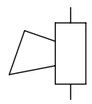
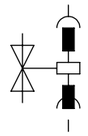
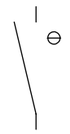
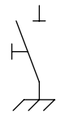
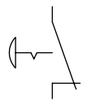
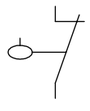
	FUSE		BATTERY		KEY SWITCH NORMALLY OPEN
	RELAY		ALTERNATOR		LEVER SWITCH NORMALLY CLOSED
	CONNECTOR		BEACON		OIL PRESSURE SWITCH
	JUMPER BAR		HORN		STANDARD SOLENOID VALVE WITH CONNECTION
	MALE & FEMALE CONNECTOR		LIGHT		WATER TEMP. SWITCH
	CONNECTOR (FEMALE)		CHASSIS EARTH		VARIABLE RESISTOR
	CONNECTOR (MALE)		PE EARTHING SWITCH		PRESSURE SWITCH
	CABLE CONNECTION		E-STOP		LIGHT WITH INTERNAL SWITCH
	2ND+ NORMALLY CLOSED CONTACT		FLOAT-LEVEL SWITCH NORMALLY CLOSED		TACOMETER
	2ND+ NORMALLY OPEN CONTACT		GLOW PLUG		STARTER MOTOR

Description: SCHEMATIC SYMBOL KEY			
Drawn by: SB	Drawn Date: 10/09/2019		
Checked/Approved by: **JOHN FARROW**	Checked/Approved Date: 17/09/2019		
SIGNATURE:			
Drawing Number: 800105100	Sheet Size: A3	Sheet: 6 of 9	Revision: **A**

800105100				**DUKE ELECTRONICS**
	800105110			**CORE ELECTRONICS [DUKE BOX]**
		800105107		STEEL WALL BOX ENCLOSURE GREY (300 X 250 X 150MM) BASE MODS [DUKE]
		800100249		CHASSIS MOUNTING PLATE FOR ENCLOSURE (200 X 250 X 2MM) WITH (X4) HOLES
		800100251		STD TOP HAT SLOTTED/PUNCHED DIN RAIL (200MM)
		ST09902X478		RUBBER SHOCK MOUNT M8
		ST11404X224		DIN RAIL END STOPS EW SERIES
		ST11401X224		TERMINAL END COVERS (BEIGE)
		ST11403X224		10 POLE JUMPER BAR - SCREW IN WQV SERIES (10W FOR 2.5MM CABLE)
		ST11400X224		FEED THROUGH TERMINAL BLOCK BLUE 2.5MM 32A WDU SERIES
		ST11407X224		FEED THROUGH TERMINAL BLOCK BEIGE 2.5MM 32A WDU SERIES
		800100131		FUSE 5 AMP (5X20)
		800100132		FUSE 10 AMP (5X20)
		800100182		FUSE 15 AMP (5X20)
		800100129		FUSEHOLDER SKT SERIES 5X20 FUSE
		800100236		FINDER RELAY MODULE + 34 SERIES 12V DC RELAY
		800105104		**DUKE ENGINE ELECTRONICS**
			800100190	ENGINE STARTER & PRE-HEAT 12V 120A RELAY
			800100203	JUNCTION BOX IP65 153 x 110 x 66MM
				SAFTEY
		C100X0166		COMPACT EMERGENCY BUTTON, TWIST TO RESET, RED 40MM MUCHROOM HEAD
		ST10288X224		EMERGENCY STOP LEGEND PLATE
		800100145		TIR BATTERY ISOLATOR SWITCH WITH REMOVABLE KEY 250A 24V (RED)
		800100164		SOUND BEACON WITH AMBER LIGHT 110DB 9-30V DC
		800100269		HEADER TANK HORIZONTAL MOUNTING FLOAT SWITCH [FLYING LEAD SSF212X100]
				CONDUIT
		ST22016X224		SWIVEL CABLE CONDUIT FITTING (12MM)
		ST22137X224		SWIVEL CABLE CONDUIT FITTING (16MM)
		ST22018X224		BRASS CABLE GLAND LOCKNUT M16
		93030030000		PVC COATED GALVANISED STEEL FLEXIBLE CONDUIT BLACK (16MM)
		ST22017X224		PVC COATED GALVANISED STEEL FLEXIBLE CONDUIT BLACK (12MM)
		ST11388X224		T PIECE CABLE CONDUIT FITTING NYLON (16MM)
				CABLE & FITTINGS
		800100110		HEATSHRINK ADHESIVE LINED TUBING (19MM)
		800100111		HEATSHRINK ADHESIVE LINED TUBING (24MM)
		800100100		BOOTLACE FERRULE 1.5MM RED (SINGLE CORE)
		800100101		BOOTLACE FERRULE 2.5MM BLUE (SINGLE CORE)
		800100103		BOOTLACE FERRULE 6MM BLACK (SINGLE CORE)
		800100252		STRAIN RELIEF GROMMET 8MM
		800100213		DEUTSCH DT SERIES 2 WAY SOCKET (BLACK)
		800100212		DEUTSCH DT SERIES 2 WAY PLUG (BLACK)
		800100214		DEUTSCH DT SERIES 2 WAY WEDGELOCK (GREEN)
		800100215		DEUTSCH DT SERIES 2 WAY WEDGELOCK (ORANGE)
		800100176		2 CORE COILED CABLE 0.75MM YELLOW (1M)
		ST11125X163		13MM BLACK STAINLESS STEEL P-CLIP
		ST11197X163		6MM P-CLIP RUBBER LINED JCS
		800100268		CABLE CLEATS (27.8 0 30.4MM)
				LIGHTS
		800100265		WORKING LAMP 6 X LED 12-24V
		800100189		RELAY JUNCTION BOX 100X100X50 (IP65)

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
-	-	-	-
-	-	-	-
-	-	-	-

Document Type: SCHEMATIC DRAWING

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BN18 0HY

Description: DUKE ELECTRICAL PARTS LIST

Drawn by: SB

Drawn Date: 10/09/2019

Checked/Approved by: JOHN FARROW

Checked/Approved Date: 17/09/2019

SIGNATURE:

Drawing Number: 800105100

Sheet Size: A3

Sheet: 7 of 9

Revision: A

				POWER
		800100175		12V NUMAX 655 COMMERCIAL BATTERY
		800100146		COPPER TUBE TERMINALS 35MM CABLE (10MM)
		800100147		COPPER TUBE TERMINALS 35MM CABLE (12MM)
		800100143		RED PVC BATTERY CABLE 35MM 240A
		800100144		BLACK PVC BATTERY CABLE 35MM 240A
		800100150		NEGATIVAL BATTERY TERMINAL CLAMP
		800100151		POSITIVE BATTERY TERMINAL CLAMP
		800100148		BATTERY TERMINAL COVER POSITIVE (RED)
		800100149		BATTERY TERMINAL COVER NEGATIVE
				CONTROL CONSOLE
		800100257		IGNITION SEALED KEYLOCK SWITCH WITH KEY BOOT (3 POSITION)
		800100180		CIGARETTE LIGHTER SOCKET
		C100G01664		ROCKER SWITCH MOUNTING PANEL (3 BLANK) V SERIES
		C100G01665		Illuminated Rectangular Black SPST Rocker Switch 12V 20A
		C100X0167		ROTARY SWITCH PANEL SPST OFF-(ON)
		800100245		ROTARY SWITCH QUICK CONNECT 3 WAY IP67 24V
		C102C01613		ROCKER SWITCH PANEL MOUNT 1 BANK (RS 881-5718)
		800100240		DEUTSCH DT SERIES, 2 ROW 6 WAY PLUG CONNECTOR
		800100258		DEUTSCH DT SERIES 6 WAY WEDGELOCK (GREEN)
		800100259		FUEL GUAGE 12V (BLACK)
		800100260		TACHOMETERS WITH HOUR METTER 12V (BLACK)
		800100261		LED PANEL MOUNT INDICATOR 22MM 12V IP65 (RED)
		800100262		LED PANEL MOUNT INDICATOR 22MM 12V IP65 (ORANGE)
		800100200		NEBULA 12V SWITCHED STRIP LIGHT 500MM
		800100263		PVC CABLE GROMMET (INNER DIA 6.4 WITH 10MM PANEL DIA)
		800100181		V SERIES ROCKER SWITCH BLANKING PLUG
				OTHER
		C102C0085		HEAVY DUTY 3 PIN 12V METAL PLUG
		C100C0086		FUEL SENDER UNIT
	800105102			**TRAILER DUKE ELECTRONICS**
		800100270		13 PIN IN-LINE FLYING SOCKET 12V
		800100185		RADEX 6900 6-F CLUSTER RH
		800100186		RADEX 6900 6-F CLUSTER LH
		800100183		REVERSING ALARM HEAVY DUTY 12-48V (97dB)
		800100187		ASPOCK REGPOINT PLATE LAMP LARGE
		800100184		WIRING HARNESS WITH 13 PIN PLUG (6M)
		800100272		CONNECTION LEAD 13-PIN TYPE WITH 2 X 8-PIN PLUGS
		800100207		PVC CABLE GROMMET 9.5MM CABLE - 12.5MM PANEL DIA
		800100278		STALK MOUNTED ANGLED LED MARKER LIGHTS LEFT
		800100277		STALK MOUNTED ANGLED LED MARKER LIGHTS RIGHT
	800105105			**TRACKED DUKE ELECTRONICS**
		800100183		ALARM HEAVY DUTY 12-48V (97dB)
		800100284		GREEN LED FLASHING BEACON LLP SERIES
		800105111		AS JOYSTICKS REMOTE [DUKE]
		C102C0132		16 WAY MALE-FEMALE 16A PANEL SOCKET KIT

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
-	-	-	-
-	-	-	-
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Dando Drilling International Ltd
Unit G
Ford Airfield Industrial Estate,
Ford, Nr. Arundel,
West Sussex.
BN18 0HY

Description: DUKE ELECTRICAL PARTS LIST

Drawn by: SB

Drawn Date: 10/09/2019

Checked/Approved by: JOHN FARROW

Checked/Approved Date: 17/09/2019

SIGNATURE:

Drawing Number: 800105100

Sheet Size: A3

Sheet: 8 of 9

Revision: A

REVISION			
REVISION	DESCRIPTION	DATE	INITIALS
A	INITIAL RELEASE	10/09/2019	SB
-	-	-	-
-	-	-	-
-	-	-	-

DANDO INTERNATIONAL DRILLING - CABLE SPECIFICATION: (2017)

COLOUR		DESCRIPTION	CABLE CORE DIAMETER 1.5MM	2.5MM	4.0MM	6.0MM	DANDO CABLE PART NUMBER			
RED		24V (TRI-RATED)	✓	✓	✓	✓	*800100112*	*800100113*	*800100114*	*800100115*
ORANGE		12V (TRI-RATED)	✓	✓	✓	✓	*800100116*	*800100117*	*800100118*	*800100119*
BLACK		CHASSIS EARTH (TRI-RATED)	✓	✓	✓	✓	*800100120*	*800100121*	*800100122*	*800100123*
BLUE		24V INPUT - ANALOG & DIGTAIL SIGNAL (TRI-RATED)	✓	✓	X	X	*800100124*	*800100125*	*N/A*	*N/A*
WHITE		0-12V INPUT - ANALOG & DIGTAIL SIGNAL (TRI-RATED)	✓	✓	X	X	*800100126*	*800100127*	*N/A*	*N/A*

Document Type: SCHEMATIC DRAWING

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APPENDIX A

ENGINE
PERKINS 403D-15

403D-15 Industrial Open Power Unit

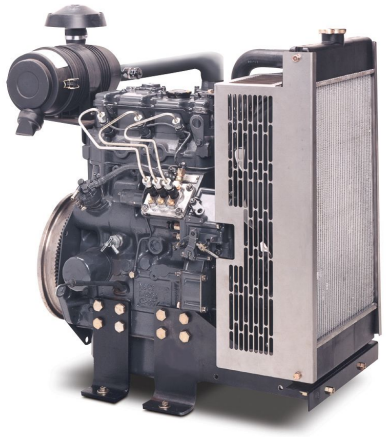
18.4-25.1 kW (24.7-33.7 hp) @ 2800-3000 rpm

EU Stage IIIA/U.S. EPA Tier 4 Interim equivalent

The Perkins 400 Series is an extensive family of engines in the 0.5-2.2 litre range. The 3 cylinder 403-15 model is the mid-range 400 Series engine, combining performance, low operating costs and a compact package. From a packaging point of view, the 403-15 is the ideal engine for small industrial applications. Its simple, robust mechanical fuel system makes it easy to install and maintain.

A 1.5 litre IOPU offering you the advantages of an industrial engine, with the convenience of a cost effective cooling and filtration solution.

Designed to meet EU Stage IIIA/U.S. EPA Tier 4 Interim equivalent emission standards.



Specifications

Power Rating		
Minimum power	20.8 kW	27.9 hp
Maximum power	24.2 kW	32.5 hp
Rated speed	2800-3000 rpm	
Maximum torque	94.4 Nm @ 1800 rpm	69.6 lb-ft @ 1800 rpm

Emission Standards	
Emissions	EU Stage IIIA/U.S. EPA Tier 4 Interim equivalent

General		
Number of cylinders	3 inline	
Bore	84 mm	3.3 in
Stroke	90 mm	3.5 in
Displacement	1.5 litres	91 cubic in
Aspiration	Naturally aspirated	
Cycle	4 stroke	
Compression ratio	22.5:1	
Combustion system	Indirect injection	
Rotation (from flywheel end)	Anti-clockwise	
Cooling system	Liquid	

403D-15 Industrial Open Power Unit

18.4-25.1 kW (24.7-33.7 hp) @ 2800-3000 rpm

EU Stage IIIA/U.S. EPA Tier 4 Interim equivalent

Total coolant capacity	6 litres	1.6 US gal
Total lubricating capacity	6 litres	1.6 US gal

Engine Dimensions*		
Length	820 mm	32.3 in
Width	497 mm	19.6 in
Height	793 mm	31.2 in
Dry weight	197 kg	434 lb

Disclaimer		
*Final dimensions dependent on selected options	0	0

Features and Benefits

A lifetime of low cost

The 400 Series offers highly competitive performance and fuel economy. Through appropriate use of technology, these engines have been designed to be reliable and to offer low cost of ownership in the wide variety of markets they serve.

Across an extensive power band, the 400 Series range offers you the ability to configure a solution to your specific machine, territory and market requirements.

Overlapping power bands between models and an extensive range of options gives the opportunity to optimise performance and functionality, adding customer value to the application.

We provide one year warranties for constant speed engines and two year warranties for variable speed models as standard.

As a 400 Series end user, you also benefit from Perkins world class product support and service coverage that comes from being a full range power solutions provider.

Compact design

The compact design of these engines makes them suitable for a range of applications, including skid steer loaders, mini excavators, wheel loaders, welders, lift platforms, lighting towers, small tractors, air compressors, turf care machinery and materials handling machinery.

Each of the six core engines of the 400 Series is configured for either Stage IIIA/Tier 4 Interim or Stage IIIB/Tier 4 Final emission standards, giving you flexibility depending on your market.

Performance and refinement

403D-15 Industrial Open Power Unit

18.4-25.1 kW (24.7-33.7 hp) @ 2800-3000 rpm

EU Stage IIIA/U.S. EPA Tier 4 Interim equivalent

The 400 Series lineup gives you a seamless power range of 8.2-50 kW (11-67 hp) in 2, 3 and 4 cylinder models designed with a family look and feel. The range offers a wide variety of ratings and configurations that can be tailored to meet the most exacting needs.
The selective use of indirect and direct injection fuel systems enables Perkins to offer world-class engine refinement and low noise levels.

Technical Information

Air inlet system

- Cast iron exhaust manifold - side outlet
- Inlet manifold
- Mounted air cleaner

Control system

- 12 volt alternator
- 12 volt starter motor
- Electronic Shut Off Solenoid (ESOS)

Cooling system

- Coolant pump belt driven
- Coolant temperature switch
- Mounted radiator and fan

Flywheel and flywheel housing

- SAE 4 flywheel housing
- SAE flywheel size 7½

Fuel system

- Fuel injection pump
- Fuel filter

General

- Cast iron engine block
- Glow plug starting aid

Oil system

- Lubricating oil pressure switch
- Lubricating oil sump
- Spin on lubricating oil filter

403D-15 Industrial Open Power Unit

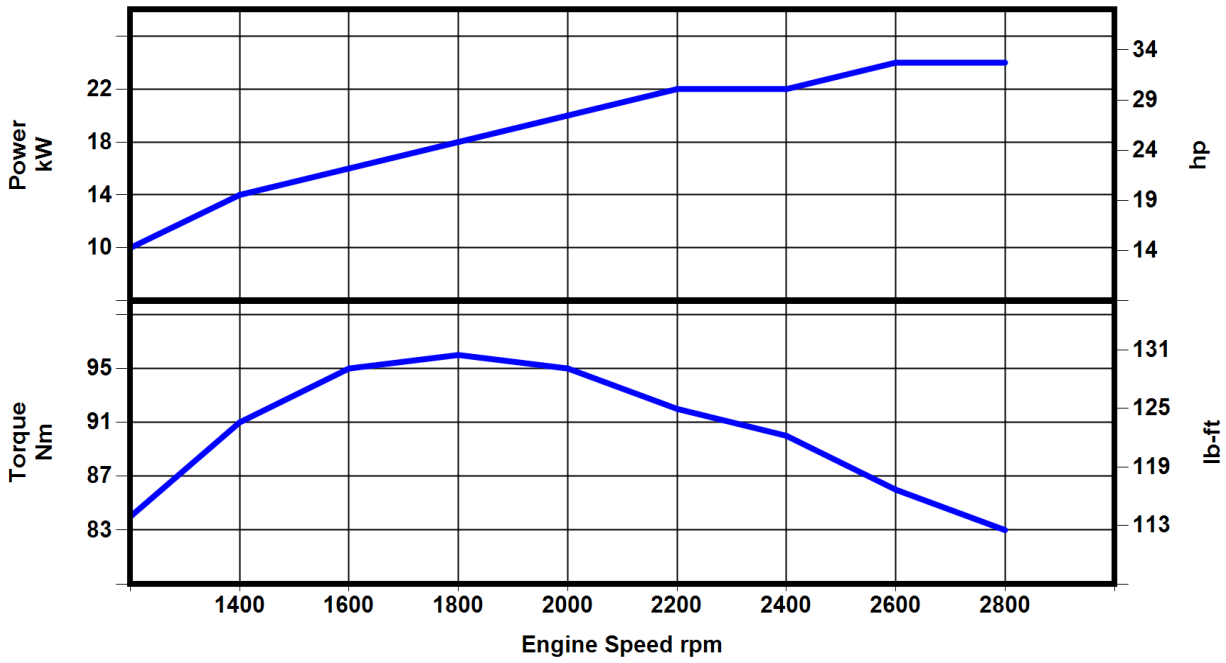
18.4-25.1 kW (24.7-33.7 hp) @ 2800-3000 rpm

EU Stage IIIA/U.S. EPA Tier 4 Interim equivalent

400 Series 403D-15 INDUSTRIAL ENGINE

EU Stage IV/U.S. EPA Tier 4 Final

24.5-24.5 kW / 32.9-32.9 hp



Power kW	Power hp	Rated Speed (rpm)	Torque Nm	Torque lb-ft	Speed (rpm)	Rating Type
24.5	32.9	2800	96.0	130	1800	Industrial C intermittent rating

Rating Standard ISO 14396:2002
Additional ratings are available for specific customer requirements. Consult your Perkins distributor.
Unless otherwise specified, all stated data is for maximum rated speed and 100% load.
B rating performance data will be added upon availability

Rating Definitions and Conditions

IND-C (Intermittent) Rating
Is the horsepower and speed capability of the engine where maximum power and/or speed are cyclic (time at full load not to exceed 50%).

Rating Conditions for Diesel Engines – up to 7.1 liters are based on ISO/TR14396, inlet air standard conditions with a total barometric pressure of 100 kPa (29.5 in. Hg), with a vapor pressure of 1 kPa (0.295 in Hg) and 25°C (77°F). Performance is measured using fuel to specification EPA 2D 89.330-96 with a density of 0.845-0.850 kg/L @ 15°C (59°F) and fuel inlet temperature 40°C (104°F).

Technical Data

403D-15

IOPU

Basic technical data

Number of cylinders ... 3
Cylinder arrangement ... Vertical in Line
Cycle ... 4 Strokes
Induction system ... N/A
Compression ratio ... 22.5:1
Bore ... 84.0 mm (3.30 in)
Stroke ... 90.0 mm (3.54 in)
Cubic capacity ... 1.496 litres (91.29 in³)
Direction of rotation ... Anti - clockwise
Firing order ... 1, 2, 3
Estimated total weight (dry) ... 197.0 kg (434 lb)
Estimated total weight (wet) ... 208.2 kg (459 lb)

Overall dimensions

-length (from x - x) ... 820 mm (32.28 in)
-width 12V (standard) (widest point) ... 497.3 mm (19.6 in)
-width 24V (optional) (widest point) ... 529.6 mm (20.9 in)
-height ... 793.0 mm (31.2 in)

Moments of inertia

-engine Includes fan pulleys, fan and flywheel: ...
-flywheel ... 2.10 kgm² (rotational components 0.45283 kgcm²)
-rotational components ... TBA

Centre of gravity (dry)

-forward from rear of block ... 179 mm
-above block centre line ... 74 mm

Performance

Notes:

- All data based on operation to ISO/TR14396, ISO3046/1 standard reference conditions
- If the engine is to operate in ambient conditions other than those of the test conditions, suitable adjustments must be made for these changes. For full details, contact Perkins Technical Service Department.
- All ratings certified to within 5 ± %.

Test conditions

-air temperature ... 25°C (°F)
-barometric pressure ... 100 kPa (14.50 lb/in²)
-relative humidity ... 30.0%

Sound level

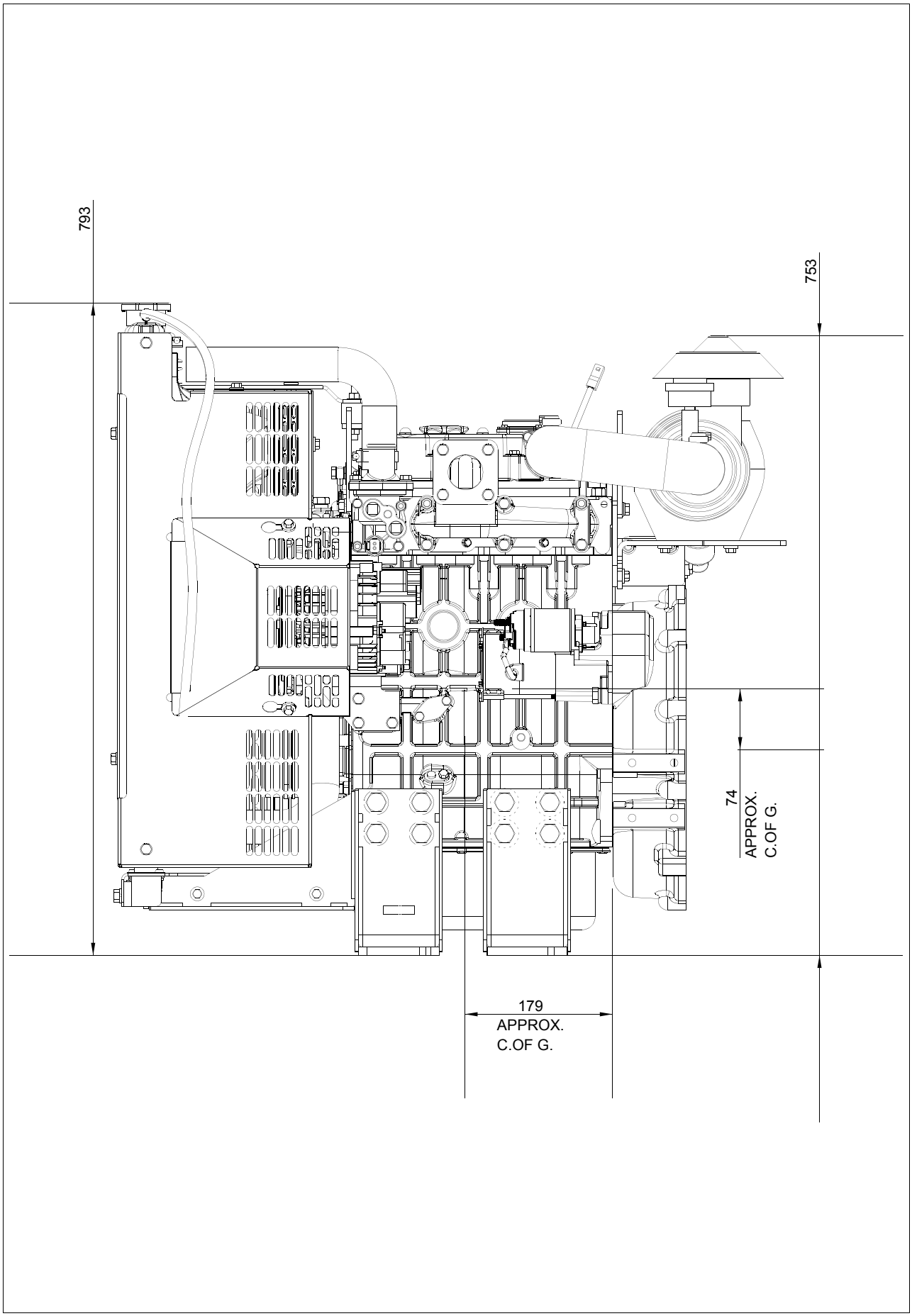
Average sound pressure level for bare engine (without inlet and exhaust) at 1 metre ... 80.4 dB(A)

General installation

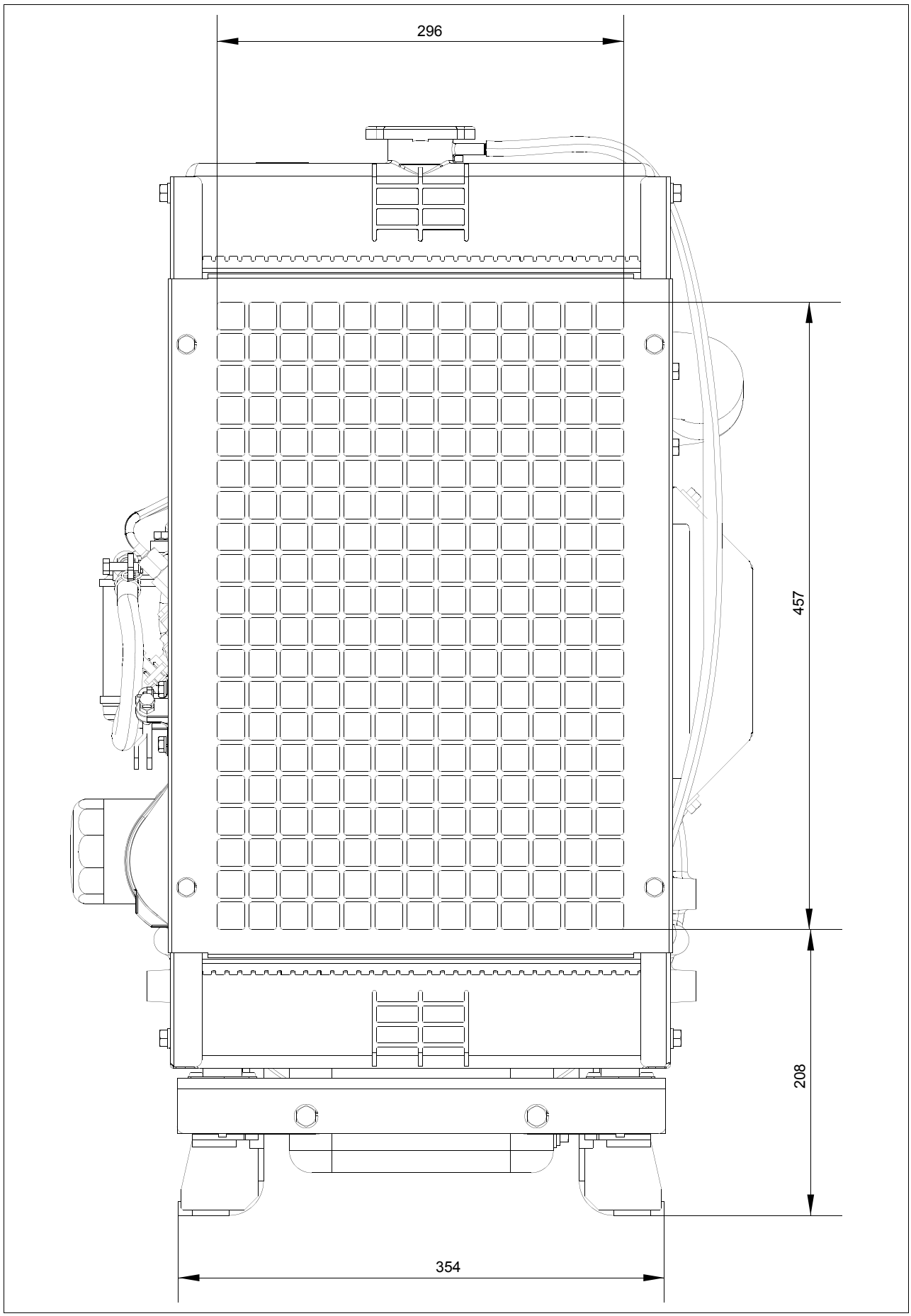
Designation	Units	Type of operation and application				
		Engine speed rev/min				
		2200	2400	2600	2800	3000
Gross engine power	kW	20.9	22.3	23.4	24.4	25.1
Brake mean effective pressure	kPa	762.3	745.5	722.1	699.2	671.3
Mean Piston speed	m/s	6.6	7.2	7.8	8.4	9.0
IOPU net engine power	kW	20.10	21.26	22.10	22.77	23.10
Engine coolant flow 35 kPa restriction	l/min	60.2	65.6	71.4	76.5	82.2
Combustion air flow	m³/min	1.50	1.62	1.75	1.87	1.98
Exhaust gas flow Max.	m³/min	4.3	4.7	5.2	5.5	5.9
Exhaust gas temperature Max.	°C	650	650	650	650	650
Cooling fan air flow (pusher)	m³/min	64.2	69.1	76.6	80.4	90.1
Energy balance						
Energy in fuel (Fuel heat of combustion)	KW	63.3	68.5	74.2	77.2	80.1
Energy to power	KW	20.9	22.3	23.4	24.4	25.1
Energy to coolant and lubricating oil	KW	20.2	21.9	23.7	24.7	25.5
Energy to exhaust	KW	16.7	18.2	20.1	21.0	22.0
Energyto radiation	KW	5.5	6.1	7.0	7.1	7.5

Caution: *The airflows shown in this table will provide acceptable cooling for an open power unit operating in ambient temperatures of up to 53°C (46°C if a canopy fitted). If the power unit is to be enclosed totally, a cooling test should be done to check that the engine cooling is acceptable. If there is insufficient cooling, contact Perkins Technical Service Department.*

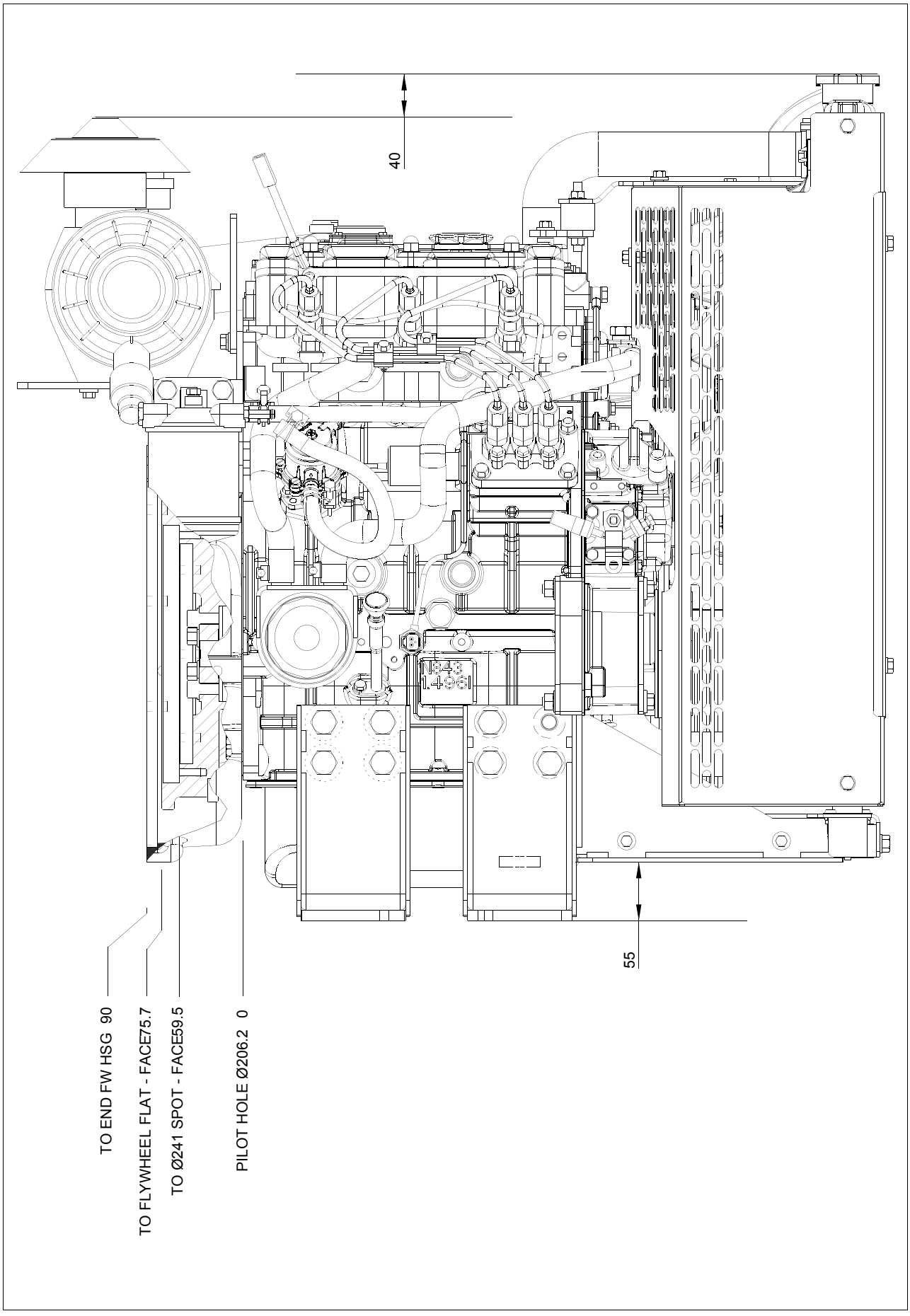
403D-15 IOPU - Left side view



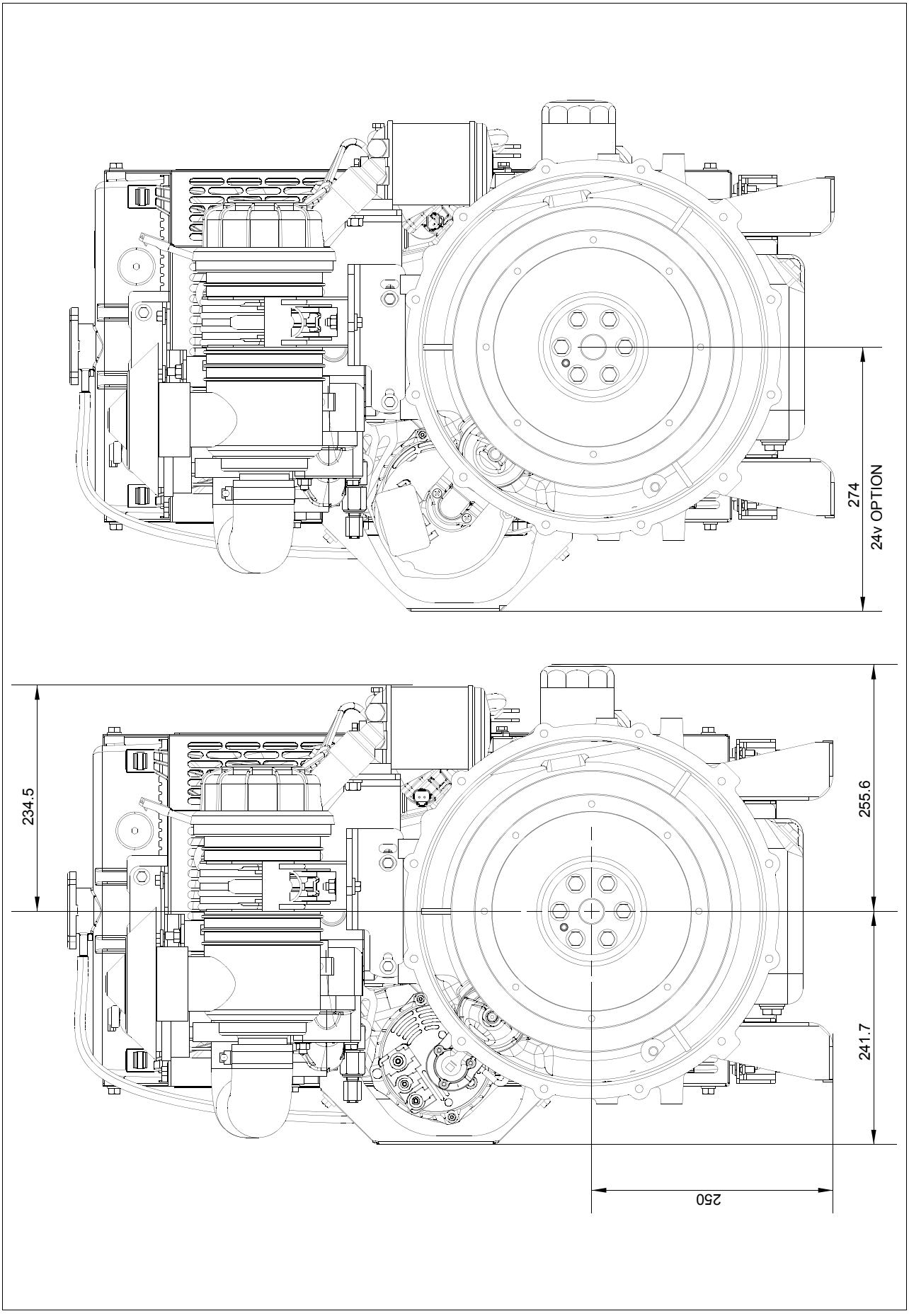
403D-15 IOPU - Front view



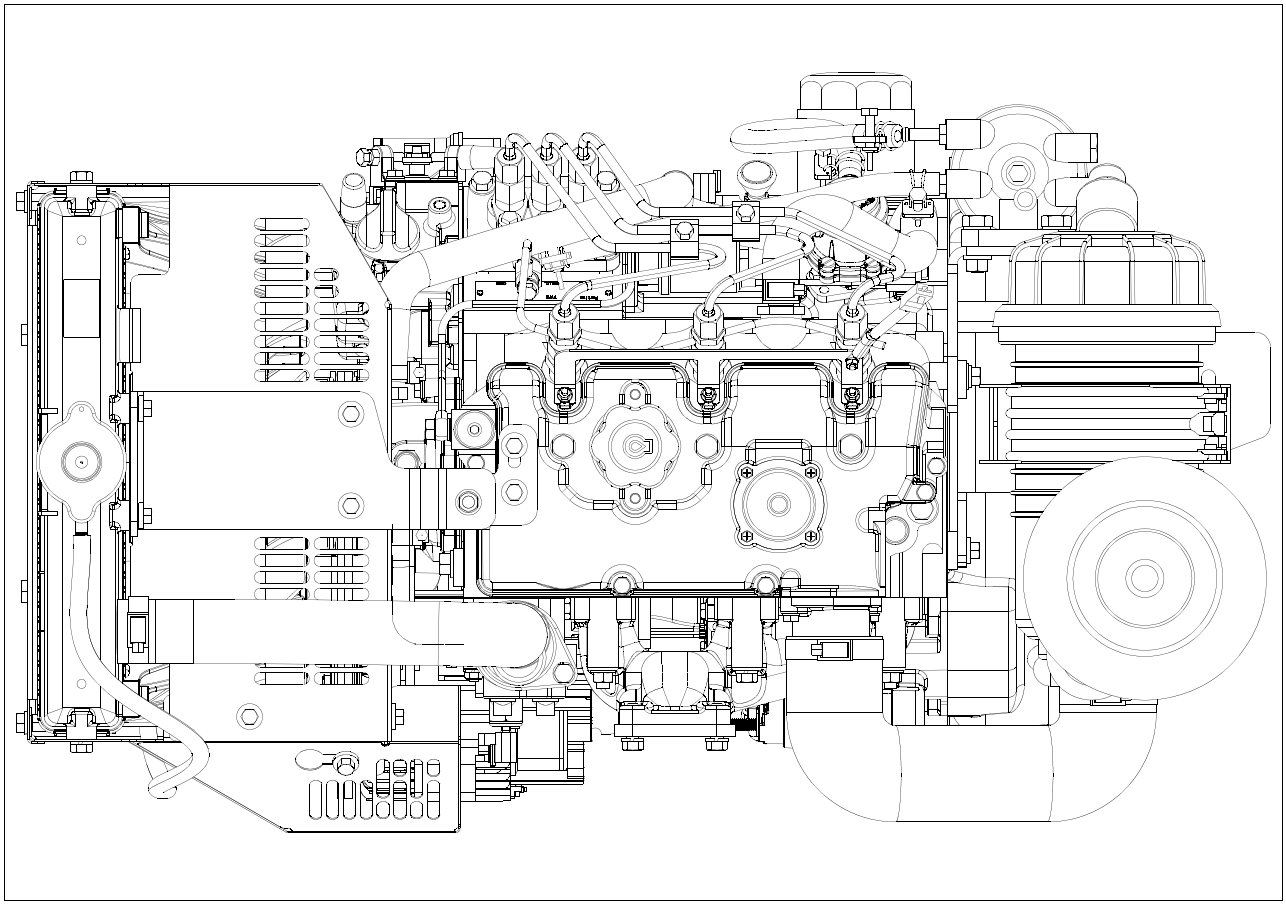
403D-15 IOPU - Right side view



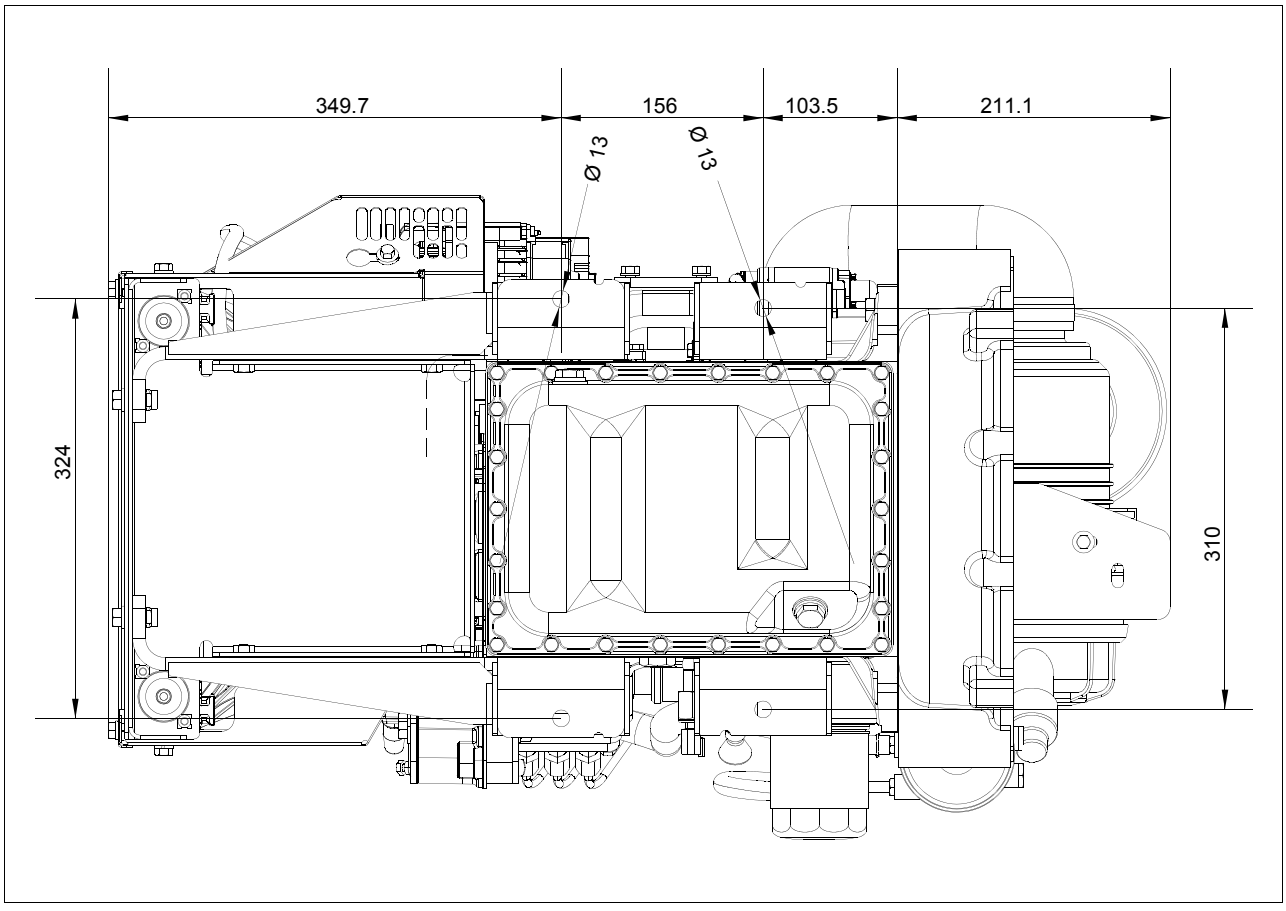
403D-15 IOPU - Rear view



403D-15 IOPU - Plan view



403D-15 IOPU - Underneath view



Cooling system

Radiator

-face area .. .. 0.165 m² (1.78 ft)
-rows and materials. ... ... 2 Row Aluminium
-gills/inch and material ... ... 14.5 Aluminium fins per inch
-width of matrix ... ... 330.0 mm (13.0 in)
-height of matrix .. .. 500.0 mm (19.68 in)
-pressure cap setting. ... ... 95.0kPa (13.8 lb/in²)

Fan

-diameter ... ... 320 mm (12.6 in)
-drive ratio 1.25:1
-number of blades 7
-material ... ...Plastic
-type .. ..Pusher

Coolant

Recommended coolant: 50% ethylene glycol with a corrosion inhibitor (BS 658 :1992 or MOD AL39) and 50% clean fresh water.
Total system capacity
-with radiator . ...5.98 l (10.5 pt)
-without radiator ... ... 2.6 l (4.6 pt)
Maximum top tank temperature ... ... 110°C (230°F)
Thermostat operation range.. ... ... 82 - 95°C (179 - 203°F)

Electrical system

-alternator.. ... ... 12V standard (24V optional)
-starter motor. ... ... 12V standard (24V optional)

Cold start recommendations

Minimum cranking speed .. .. 150 rev/min

Battery type

Minimum starting temperature	Grade of engine lubricating oil	Battery specifications			
		BS3911 cold start amps	SAEJ537 cold cranking amps	Number of batteries required	Commercial reference
0°C	20W	420	590	1	072
- 15°C	10W	420	590	1	072
- 20°C	5W	540	740	1	647

Exhaust system

Maximum back pressure for total system ... . 10.2 kPa (1.47 lb/in²)
Inside diameter of outlet flange .. ..42.0 mm (1.6 in)

Fuel system

Type of injection . ... Pintle nozzle
Fuel injection pump ... ...Cassette type
Nozzle opening pressure ... ... 14.7 MPa (2.13 lb/in²)

Fuel lift pump

-flow/hour ... ... 63 l/hr (13.8 gal/hr)
-pressure ... ... 10.0 kPa (lb/in²)
Maximum suction head .. .. 0.8 m using 6 mm Ø bore pipe
Maximum pressure head ... ... 3 m using 6mm bore pipe
Governor type. ... ...Mechanical

Fuel specification

USA FED Off Highway

Density ... ... 0.840 - 0.865 (kg/l @ 15°C)
Viscosity . ... 2.0 - 3.2 (mm²/s @ 40°C)
Sulphur content .. .. 0.0007 - 0 0.0015 (% mass)
Cetane No .. .. .40 - 50

Europe Off Highway EU 2004/26/EC Stage 3B/4

Density ... ... 0.833 - 0.837 (kg/l @ 15°C)
Viscosity . ... 2.3 - 3.3 (mm²/s @ 40°C)
Sulphur content .. ..0.001 Max. (% mass)
Cetane No .. ..54 Max.

Fuel consumption

Fuel consumption given 100% power rating @ rev/min					
rev/min	2200	2400	2600	2800	3000
sfc g/kWh	262	269	266	276	272
litres/ hour	6.6	7.2	7.5	8.1	8.2

Induction system

Maximum permissible air intake restriction

-clean filter.. ... ... 3.0 kPa
-dirty filter ... ... 6.4 kPa
-air filter type... ... ... Dry Element Type

Lubrication system

Lubricating oil capacity

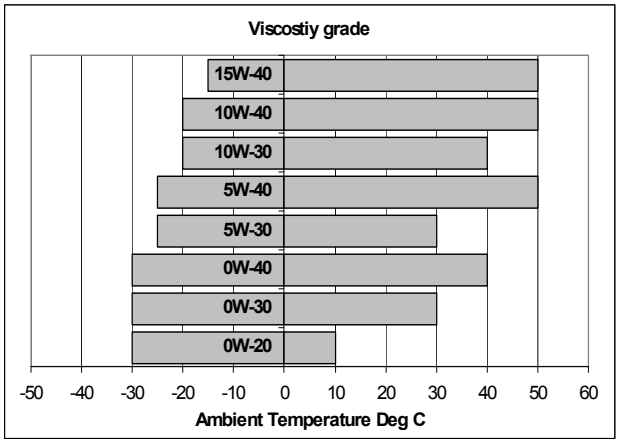
-total system... ... ... 6.0 l (10.6 pt) unbalanced
-minimum .. .. 4.5 l (7.91 pt) unbalanced
Maximum engine operating angles ... ... 35° unbalanced

Lubricating oil pressure

-relief valve opens.. ... ... 304 - 500 kPa (44 - 73 lb/in²)
-at maximum no - load speed ... . 196 - 470 kPa (28 - 68 lb/in²)
Max continuous oil temperature. ... 125°C Max, 135°C intermittent

Recommended SAE viscosity

A single or multi grade lubricating oil which conforms to API CG4 / CH4 or ACEA E3 / E5 must be used, see illustration below:



Mountings

Maximum bending moment at
rear face of block . ... TBA Nm (lbf ft)

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Perkins®
THE HEART OF EVERY GREAT MACHINE

SEBU8311-04 (en-us)
February 2016

Operation and Maintenance Manual

400A and 400D Industrial Engines

GG (Engine)
GH (Engine)
GJ (Engine)
GK (Engine)
GL (Engine)
GM (Engine)
GN (Engine)
GP (Engine)
GR (Engine)
GS (Engine)
GT (Engine)
GU (Engine)
GV (Engine)

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the “Safety Alert Symbol” and followed by a “Signal Word” such as “DANGER”, “WARNING” or “CAUTION”. The Safety Alert “WARNING” label is shown below.

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

Perkins cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Perkins is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Perkins dealers or Perkins distributors have the most current information available.

⚠ WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

Table of Contents

Foreword

Literature Information

This manual contains safety, operation instructions, lubrication and maintenance information. This manual should be stored in or near the engine area in a literature holder or literature storage area. Read, study and keep it with the literature and engine information.

English is the primary language for all Perkins publications. The English used facilitates translation and consistency.

Some photographs or illustrations in this manual show details or attachments that may be different from your engine. Guards and covers may have been removed for illustrative purposes. Continuing improvement and advancement of product design may have caused changes to your engine which are not included in this manual. Whenever a question arises regarding your engine, or this manual, please consult with your Perkins dealer or your Perkins distributor for the latest available information.

Safety

This safety section lists basic safety precautions. In addition, this section identifies hazardous, warning situations. Read and understand the basic precautions listed in the safety section before operating or performing lubrication, maintenance and repair on this product.

Operation

Operating techniques outlined in this manual are basic. They assist with developing the skills and techniques required to operate the engine more efficiently and economically. Skill and techniques develop as the operator gains knowledge of the engine and its capabilities.

The operation section is a reference for operators. Photographs and illustrations guide the operator through procedures of inspecting, starting, operating and stopping the engine. This section also includes a discussion of electronic diagnostic information.

Maintenance

The maintenance section is a guide to engine care. The illustrated, step-by-step instructions are grouped by service hours and/or calendar time maintenance intervals. Items in the maintenance schedule are referenced to detailed instructions that follow.

Recommended service should be performed at the appropriate intervals as indicated in the Maintenance Interval Schedule. The actual operating environment of the engine also governs the Maintenance Interval Schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

The maintenance schedule items are organized for a preventive maintenance management program. If the preventive maintenance program is followed, a periodic tune-up is not required. The implementation of a preventive maintenance management program should minimize operating costs through cost avoidances resulting from reductions in unscheduled downtime and failures.

Maintenance Intervals

Perform maintenance on items at multiples of the original requirement. We recommend that the maintenance schedules be reproduced and displayed near the engine as a convenient reminder. We also recommend that a maintenance record be maintained as part of the engine's permanent record.

Your authorized Perkins dealer or your Perkins distributor can assist you in adjusting your maintenance schedule to meet the needs of your operating environment.

Overhaul

Major engine overhaul details are not covered in the Operation and Maintenance Manual except for the interval and the maintenance items in that interval. Major repairs should only be carried out by Perkins authorized personnel. Your Perkins dealer or your Perkins distributor offers a variety of options regarding overhaul programs. If you experience a major engine failure, there are also numerous after failure overhaul options available. Consult with your Perkins dealer or your Perkins distributor for information regarding these options.

California Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm. Battery posts, terminals and related accessories contain lead and lead compounds. **Wash hands after handling**.

Safety Section

i02959960

Safety Messages

There may be several specific warning signs on your engine. The exact location and a description of the warning signs are reviewed in this section. Please become familiar with all warning signs.

Ensure that all of the warning signs are legible. Clean the warning signs or replace the warning signs if the words cannot be read or if the illustrations are not visible. Use a cloth, water, and soap to clean the warning signs. Do not use solvents, gasoline, or other harsh chemicals. Solvents, gasoline, or harsh chemicals could loosen the adhesive that secures the warning signs. The warning signs that are loosened could drop off of the engine.

Replace any warning sign that is damaged or missing. If a warning sign is attached to a part of the engine that is replaced, install a new warning sign on the replacement part. Your Perkins dealer or your distributor can provide new warning signs.

(A) Universal Warning

⚠ WARNING

Do not operate or work on this equipment unless you have read and understand the instructions and warnings in the Operation and Maintenance Manuals. Failure to follow the instructions or heed the warnings could result in serious injury or death.

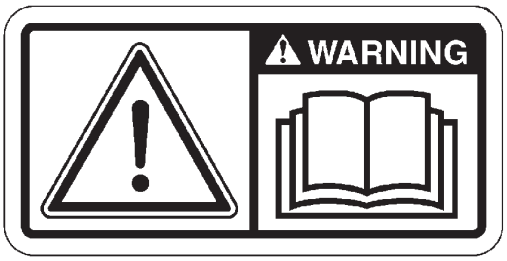

Illustration 1 g01154807

Typical example

Warning label (A) is installed in different locations. The location will change according to the physical size of the engine.

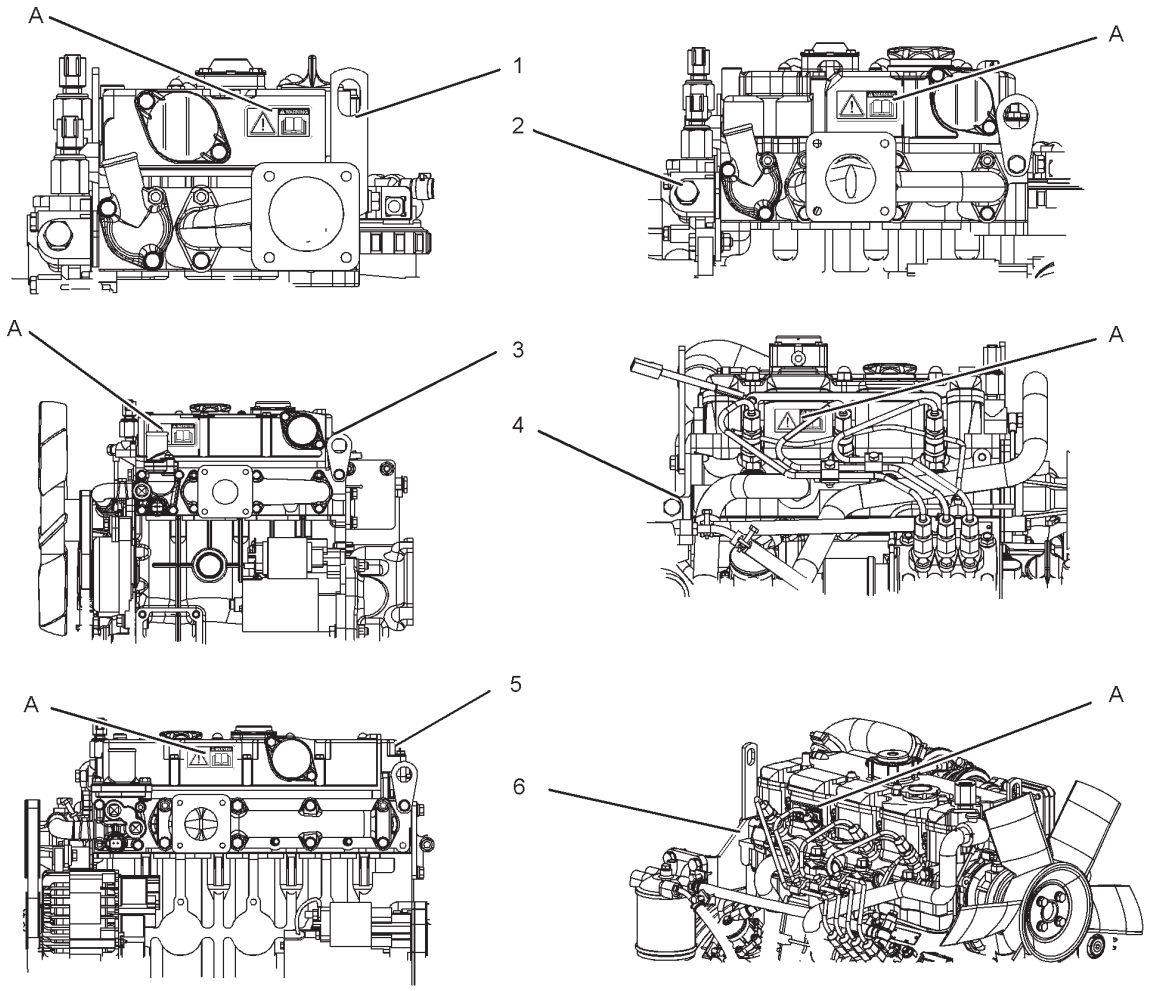

Illustration 2 g01324126

(A) Location of warning label
(1) 402D-05
(2) 403D-07
(3) 403D-11
(4) 403D-15, 403D-15T and 403D-17
(5) 404D-15
(6) 404D-22, 404D-22T and 404D-22TA

i05875556

General Hazard Information

Illustration 3 g00104545

Attach a “Do Not Operate” warning tag or a similar warning tag to the start switch or to the controls before you service the equipment or before you repair the equipment.

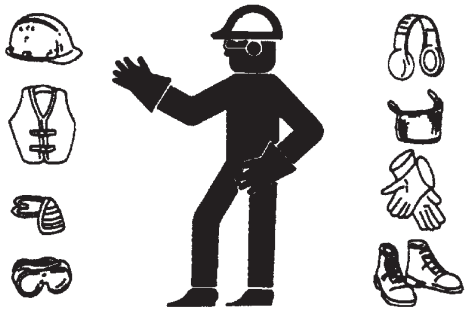

Illustration 4 g00702020

Wear a hard hat, protective glasses, and other protective equipment, as required.

Do not wear loose clothing or jewelry that can snag on controls or on other parts of the engine.

Make sure that all protective guards and all covers are secured in place on the engine.

Keep the engine free from foreign material. Remove debris, oil, tools, and other items from the deck, from walkways, and from steps.

Never put maintenance fluids into glass containers. Drain all liquids into a suitable container.

Obey all local regulations for the disposal of liquids.

Use all cleaning solutions with care.

Report all necessary repairs.

Do not allow unauthorized personnel on the equipment.

Disconnect the batteries when maintenance is performed or when the electrical system is serviced. Disconnect the battery ground leads. Tape the leads in order to help prevent sparks. If equipped, allow the diesel exhaust fluid to be purged before disconnecting the battery.

Perform maintenance on the engine with the equipment in the servicing position. Refer to the OEM information for the procedure for placing the equipment in the servicing position.

Do not attempt any repairs that are not understood. Use the proper tools. Replace any equipment that is damaged or repair the equipment.

For initial start-up of a new engine or for starting an engine that has been serviced, make provisions to stop the engine if an overspeed occurs. The stopping of the engine may be accomplished by shutting off the fuel supply and/or the air supply to the engine. Ensure that only the fuel supply line is shut off. Ensure that the fuel return line is open.

Start the engine from the operators station (cab). Never short across the starting motor terminals or the batteries. This action could bypass the engine neutral start system and/or the electrical system could be damaged.

Engine exhaust contains products of combustion which may be harmful to your health. Always start the engine and operate the engine in a ventilated area. If the engine is in an enclosed area, vent the engine exhaust to the outside.

Use caution when cover plates are removed. Gradually loosen, but do not remove the last two bolts or nuts that are located at opposite ends of the cover plate or the device. Before removing the last two bolts or nuts, pry the cover loose in order to relieve any spring pressure or other pressure.

Pressure Air and Water

Pressurized air and/or water can cause debris and/or hot water to be blown out. This action could result in personal injury.

The direct application of pressurized air or pressurized water to the body could result in personal injury.

When pressurized air and/or water is used for cleaning, wear protective clothing, protective shoes, and eye protection. Eye protection includes goggles or a protective face shield.

The maximum air pressure for cleaning purposes must be below 205 kPa (30 psi). The maximum water pressure for cleaning purposes must be below 275 kPa (40 psi).

Fluid Penetration

Pressure can be trapped in the hydraulic circuit long after the engine has been stopped. The pressure can cause hydraulic fluid or items such as pipe plugs to escape rapidly if the pressure is not relieved correctly.

Do not remove any hydraulic components or parts until pressure has been relieved or personal injury may occur. Do not disassemble any hydraulic components or parts until pressure has been relieved or personal injury may occur. Refer to the OEM information for any procedures that are required to relieve the hydraulic pressure.

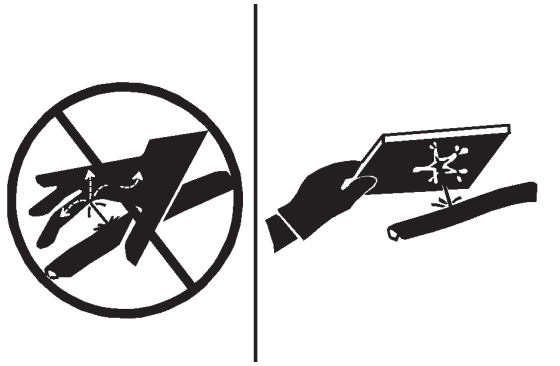

Illustration 5 g00687600

Always use a board or cardboard when you check for a leak. Leaking fluid that is under pressure can penetrate body tissue. Fluid penetration can cause serious injury and possible death. A pin hole leak can cause severe injury. If fluid is injected into your skin, you must get treatment immediately. Seek treatment from a doctor that is familiar with this type of injury.

Containing Fluid Spillage

Care must be taken in order to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting, and repair of the engine. Make provision to collect the fluid with a suitable container before any compartment is opened or before any component is disassembled.

- Only use the tools that are suitable for collecting fluids and equipment that is suitable for collecting fluids.
- Only use the tools that are suitable for containing fluids and equipment that is suitable for containing fluids.

Obey all local regulations for the disposal of liquids.

i05875580

Burn Prevention

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine. Relieve all pressure in the air system, in the hydraulic system, in the lubrication system, in the fuel system, or in the cooling system before any lines, fittings, or related items are disconnected.

Coolant

When the engine is at operating temperature, the engine coolant is hot. The coolant is also under pressure. The radiator and all lines to the heaters or to the engine contain hot coolant.

Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained.

Check that the coolant level after the engine has stopped and the engine has been allowed to cool.

Ensure that the filler cap is cool before removing the filler cap. The filler cap must be cool enough to touch with a bare hand. Remove the filler cap slowly in order to relieve pressure.

Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

Oils

Skin may be irritated following repeated or prolonged exposure to mineral and synthetic base oils. Refer to your suppliers Material Safety Data Sheets for detailed information. Hot oil and lubricating components can cause personal injury. Do not allow hot oil to contact the skin. Appropriate personal protective equipment should be used.

Diesel Fuel

Diesel may be irritating to the eyes, respiratory system, and skin. Prolonged exposure to diesel may cause various skin conditions. Appropriate personal protective equipment should be used. Refer to supplier Material safety Data sheets for detailed information.

Batteries

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes. Always wear protective glasses for servicing batteries. Wash hands after touching the batteries and connectors. Use of gloves is recommended.

i05875630

Fire Prevention and Explosion Prevention

Illustration 6 g00704000

All fuels, most lubricants, and some coolant mixtures are flammable.

Flammable fluids that are leaking or spilled onto hot surfaces or onto electrical components can cause a fire. Fire may cause personal injury and property damage.

A flash fire may result if the covers for the engine crankcase are removed within 15 minutes after an emergency shutdown.

Determine whether the engine will be operated in an environment that allows combustible gases to be drawn into the air inlet system. These gases could cause the engine to overspeed. Personal injury, property damage, or engine damage could result.

If the application involves the presence of combustible gases, consult your Perkins dealer and/or your Perkins distributor for additional information about suitable protection devices.

Remove all flammable combustible materials or conductive materials such as fuel, oil, and debris from the engine. Do not allow any flammable combustible materials or conductive materials to accumulate on the engine.

Store fuels and lubricants in correctly marked containers away from unauthorized persons. Store oily rags and any flammable materials in protective containers. Do not smoke in areas that are used for storing flammable materials.

Do not expose the engine to any flame.

Exhaust shields (if equipped) protect hot exhaust components from oil or fuel spray in case of a line, a tube, or a seal failure. Exhaust shields must be installed correctly.

Do not weld on lines or tanks that contain flammable fluids. Do not flame cut lines or tanks that contain flammable fluid. Clean any such lines or tanks thoroughly with a nonflammable solvent prior to welding or flame cutting.

Wiring must be kept in good condition. Ensure that all electrical wires are correctly installed and securely attached. Check all electrical wires daily. Repair any wires that are loose or frayed before you operate the engine. Clean all electrical connections and tighten all electrical connections.

Eliminate all wiring that is unattached or unnecessary. Do not use any wires or cables that are smaller than the recommended gauge. Do not bypass any fuses and/or circuit breakers.

Arcing or sparking could cause a fire. Secure connections, recommended wiring, and correctly maintained battery cables will help to prevent arcing or sparking.

Inspect all lines and hoses for wear or for deterioration. The hoses must be correctly routed. The lines and hoses must have adequate support and secure clamps. Tighten all connections to the recommended torque. Leaks can cause fires.

Oil filters and fuel filters must be correctly installed. The filter housings must be tightened to the correct torque.

Illustration 7 g00704059

Use caution when you are refueling an engine. Do not smoke while you are refueling an engine. Do not refuel an engine near open flames or sparks. Always stop the engine before refueling.

Illustration 8 g00704135

Gases from a battery can explode. Keep any open flames or sparks away from the top of a battery. Do not smoke in battery charging areas.

Never check the battery charge by placing a metal object across the terminal posts. Use a voltmeter or a hydrometer.

Incorrect jumper cable connections can cause an explosion that can result in injury. Refer to the Operation Section of this manual for specific instructions.

Do not charge a frozen battery. This action may cause an explosion.

The batteries must be kept clean. The covers (if equipped) must be kept on the cells. Use the recommended cables, connections, and battery box covers when the engine is operated.

Fire Extinguisher

Make sure that a fire extinguisher is available. Be familiar with the operation of the fire extinguisher. Inspect the fire extinguisher and service the fire extinguisher regularly. Obey the recommendations on the instruction plate.

Ether

Ether is flammable and poisonous.

Do not smoke while you are replacing an ether cylinder or while you are using an ether spray.

Do not store ether cylinders in living areas or in the engine compartment. Do not store ether cylinders in direct sunlight or in temperatures above 49° C (120° F). Keep ether cylinders away from open flames or sparks.

Lines, Tubes, and Hoses

Do not bend high-pressure lines. Do not strike high-pressure lines. Do not install any lines that are bent or damaged. Do not clip any other items to the high-pressure lines.

Repair any lines that are loose or damaged. Leaks can cause fires. Consult your Perkins dealer or your Perkins distributor for repair or for replacement parts.

Check lines, tubes, and hoses carefully. Do not use your bare hand to check for leaks. Use a board or cardboard to check for leaks. Tighten all connections to the recommended torque.

Replace the parts if any of the following conditions are present:

- End fittings are damaged or leaking.
- Outer coverings are chafed or cut.
- Wires are exposed.
- Outer coverings are ballooning.
- Flexible parts of the hoses are kinked.
- Outer covers have embedded armoring.

- End fittings are displaced.

Make sure that all clamps, guards, and heat shields are installed correctly. During engine operation, correct installation will help to prevent vibration, rubbing against other parts, and excessive heat.

i02143194

Crushing Prevention and Cutting Prevention

Support the component correctly when work beneath the component is performed.

Unless other maintenance instructions are provided, never attempt adjustments while the engine is running.

Stay clear of all rotating parts and of all moving parts. Leave the guards in place until maintenance is performed. After the maintenance is performed, reinstall the guards.

Keep objects away from moving fan blades. The fan blades will throw objects or cut objects.

When objects are struck, wear protective glasses in order to avoid injury to the eyes.

Chips or other debris may fly off objects when objects are struck. Before objects are struck, ensure that no one will be injured by flying debris.

i05874054

Before Starting Engine

NOTICE
For initial start-up of a new or rebuilt engine, and for start-up of an engine that has been serviced, make provision to shut the engine off should an overspeed occur. This may be accomplished by shutting off the air and/or fuel supply to the engine.

⚠ WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

Inspect the engine for potential hazards.

Do not start the engine or move any of the controls if there is a “DO NOT OPERATE” warning tag or similar warning tag attached to the start switch or to the controls.

Before starting the engine, ensure that no one is on, underneath, or close to the engine. Ensure that the area is free of personnel.

If equipped, ensure that the lighting system for the engine is suitable for the conditions. Ensure that all lights work properly, if equipped.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Do not bypass the automatic shutoff circuits. Do not disable the automatic shutoff circuits. The circuits are provided in order to help prevent personal injury. The circuits are also provided in order to help prevent engine damage.

See the Service Manual for repairs and for adjustments.

i02157354

Engine Starting

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

If a warning tag is attached to the engine start switch or to the controls, DO NOT start the engine or move the controls. Consult with the person that attached the warning tag before the engine is started.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Start the engine from the operator's compartment or from the engine start switch.

Always start the engine according to the procedure that is described in the Operation and Maintenance Manual, “Engine Starting” topic in the Operation Section. Knowing the correct procedure will help to prevent major damage to the engine components. Knowing the procedure will also help to prevent personal injury.

To ensure that the jacket water heater (if equipped) and/or the lube oil heater (if equipped) is working correctly, check the water temperature gauge and the oil temperature gauge during the heater operation.

Engine exhaust contains products of combustion which can be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is started in an enclosed area, vent the engine exhaust to the outside.

Note: The engine is equipped with an automatic device for cold starting for normal conditions of operation. If the engine will be operated in very cold conditions, then an extra cold starting aid may be required. Normally, the engine will be equipped with the correct type of starting aid for your region of operation.

The 400 Series engines are equipped with a glow plug starting aid in each individual cylinder that heats the intake air in order to improve starting.

i02590389

Engine Stopping

To avoid overheating of the engine and accelerated wear of the engine components, stop the engine according to this Operation and Maintenance Manual, “Engine Stopping” topic (Operation Section).

Use the Emergency Stop Button (if equipped) ONLY in an emergency situation. DO NOT use the Emergency Stop Button for normal engine stopping. After an emergency stop, DO NOT start the engine until the problem that caused the emergency stop has been corrected.

On the initial start-up of a new engine or an engine that has been serviced, make provisions to stop the engine if an overspeed condition occurs. This may be accomplished by shutting off the fuel supply and/or the air supply to the engine.

If equipped, in order to stop an electronically controlled engine, cut the power to the engine.

i02176668

Electrical System

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause the combustible gases that are produced by some batteries to ignite.

To help prevent sparks from igniting combustible gases that are produced by some batteries, the negative “−” jump start cable should be connected last from the external power source to the negative “−” terminal of the starting motor. If the starting motor is not equipped with a negative “−” terminal, connect the jump start cable to the engine block.

Check the electrical wires daily for wires that are loose or frayed. Tighten all loose electrical wires before the engine is started. Repair all frayed electrical wires before the engine is started. See the Operation and Maintenance Manual for specific starting instructions.

Grounding Practices

Correct grounding for the engine electrical system is necessary for optimum engine performance and reliability. Incorrect grounding will result in uncontrolled electrical circuit paths and in unreliable electrical circuit paths.

Uncontrolled electrical circuit paths can result in damage to main bearings, to crankshaft bearing journal surfaces, and to aluminum components.

Engines that are installed without engine-to-frame ground straps can be damaged by electrical discharge.

To ensure that the engine and the engine electrical systems function correctly, an engine-to-frame ground strap with a direct path to the battery must be used. This path may be provided by way of a direct engine ground to the frame.

All grounds should be tight and free of corrosion. The engine alternator must be grounded to the negative “-” battery terminal with a wire that is adequate to handle the full charging current of the alternator.

Product Information Section

Model Views

i02590436

Model View Illustrations

The following model views show typical features of the 400 series engines. Due to individual applications, your engine may appear different from the illustrations.

Note: Individual components are detailed on the 404D-22T turbocharged engine only.

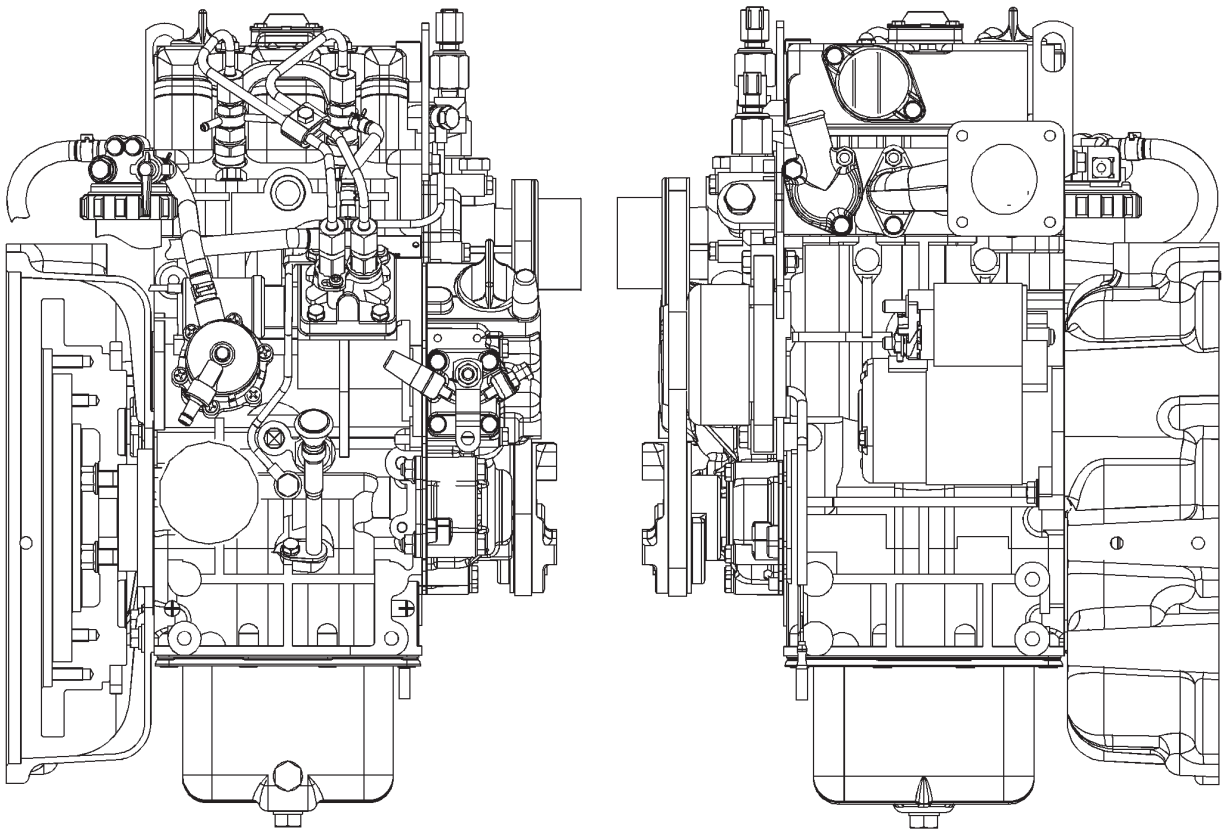

Illustration 9 g01299985

Typical view of the 402D-05 engine

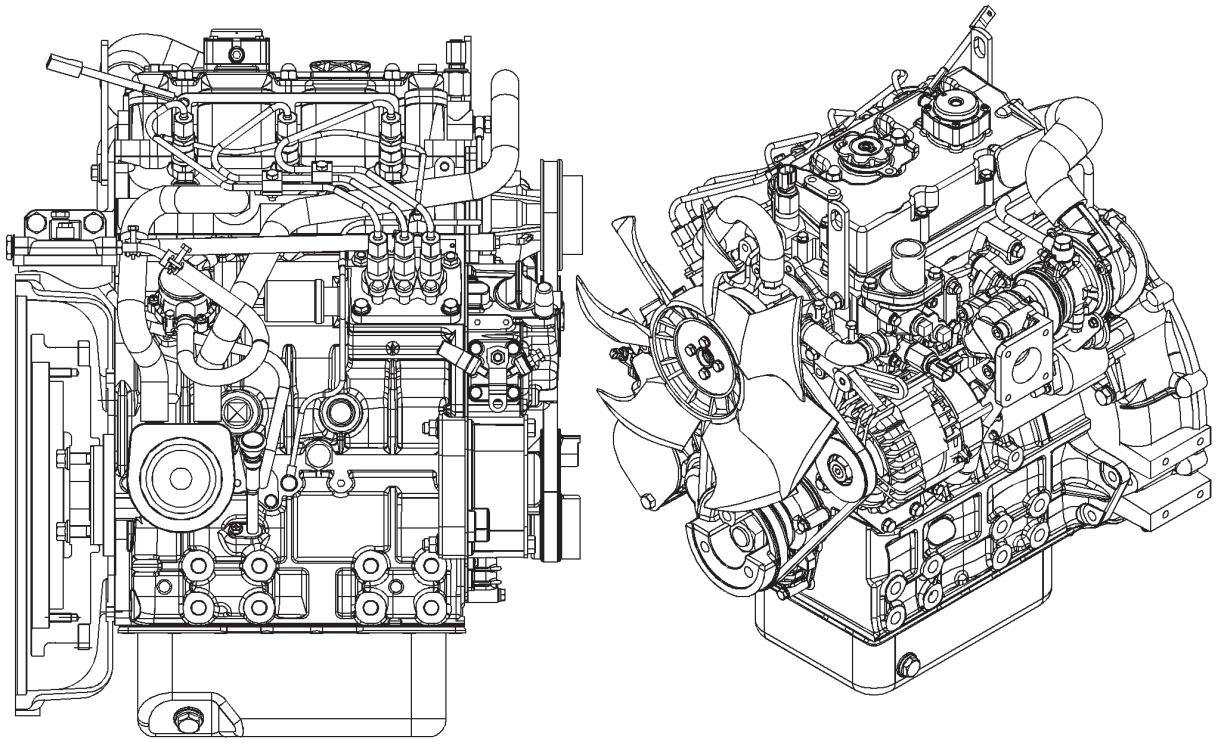

Illustration 10 g01300431
Typical view of the 403D-15T engine

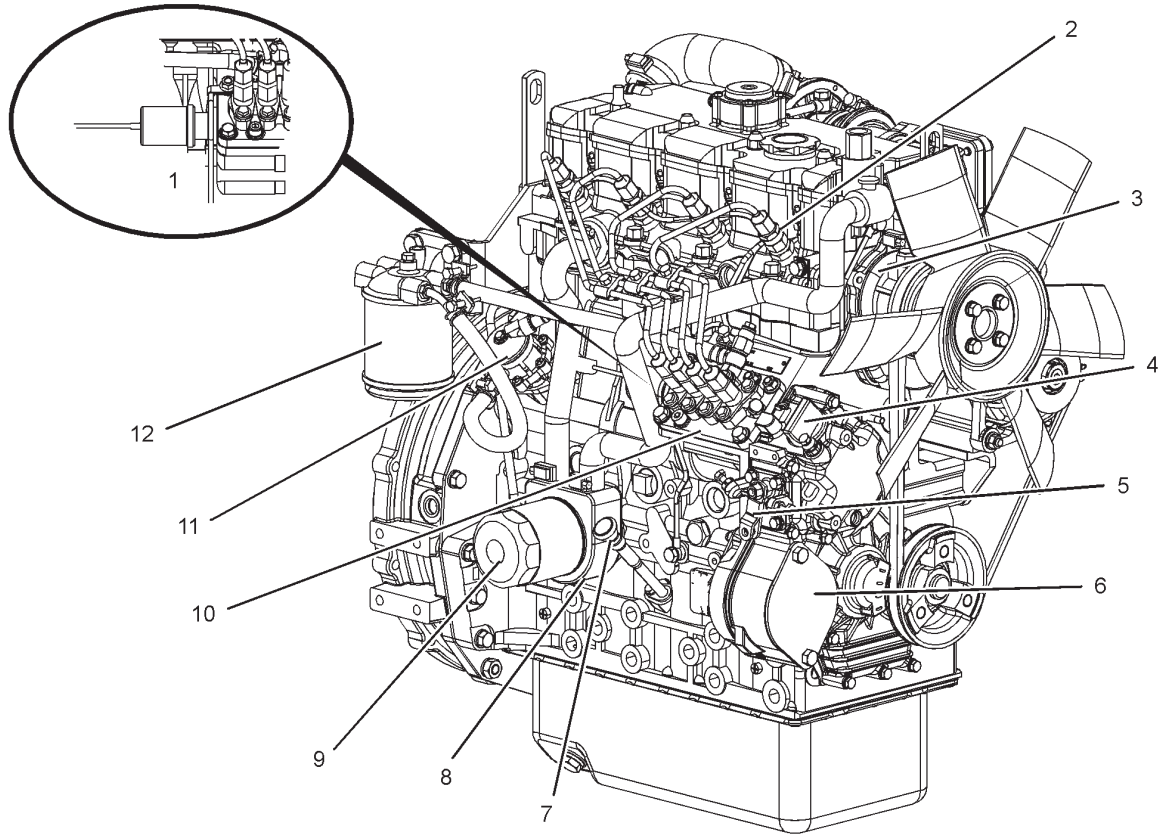

Illustration 11 g01304893

Front and right side view of the 404D-22T Engine

(1) Fuel shutoff solenoid
(2) Number one fuel injector
(3) Water pump
(4) Lower engine oil filler cap
(5) Throttle lever
(6) Cover plate for the accessory drive
(7) Engine oil level gauge
(8) Engine oil cooler
(9) Engine oil filter
(10) Fuel injection pump
(11) Transfer pump
(12) Fuel filter

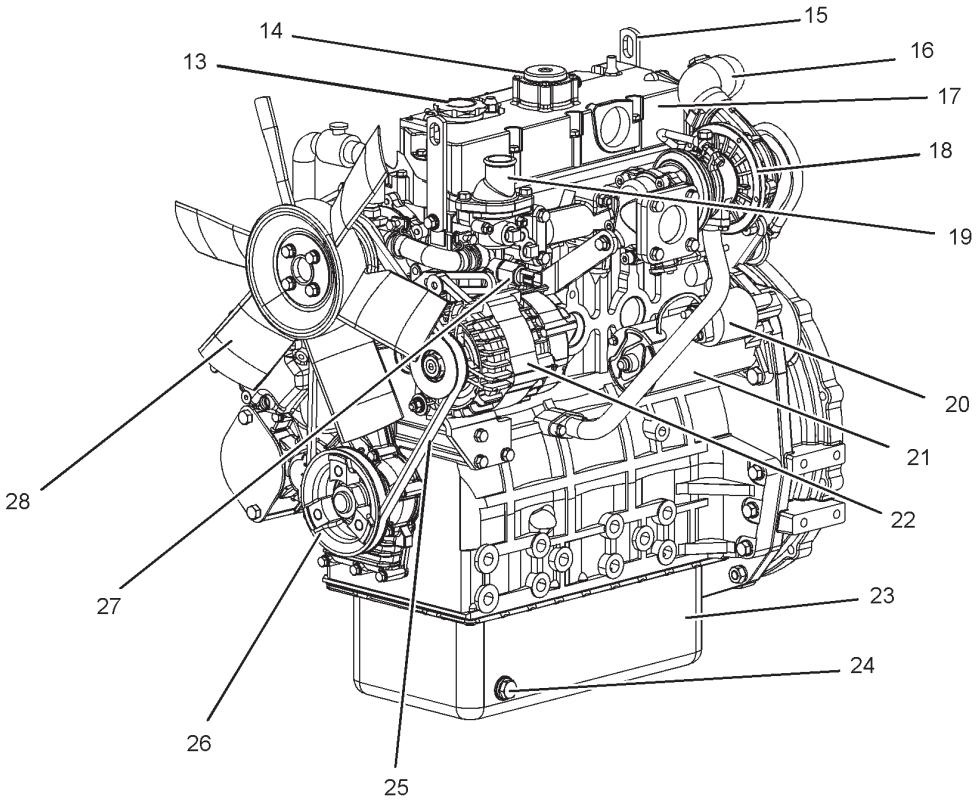

Illustration 12 g01305224

Front and left side view of the 404D-22T Engine

(13) Top engine oil filler cap
(14) Crankcase breather
(15) Rear Lifting eye
(16) Air inlet elbow
(17) Valve mechanism cover
(18) Turbocharger
(19) Water temperature regulator housing
(20) Starting motor solenoid
(21) Electric starting motor
(22) Alternator
(23) Engine oil pan
(24) Engine oil drain plug
(25) Fan drive belt
(26) Crankshaft pulley
(27) Coolant temperature switch
(28) Cooling fan

i02959055

Engine Description

The 400 series engines are indirect injection engines. The engines are controlled with a mechanically actuated fuel injection pump. The engine cylinders are arranged in-line.

The cylinder head assembly has one inlet valve and one exhaust valve for each cylinder. Each cylinder valve has a single valve spring.

The pistons have two compression rings and an oil control ring. It is important to ensure the correct piston height so that the piston does not contact the cylinder head. The correct piston height also ensures efficient combustion of fuel that is necessary in order to conform to requirements for emissions.

The crankshaft for a two cylinder engine has two main bearing journals. The crankshaft for a three cylinder engine has four main bearing journals. The crankshaft for a four cylinder engine has five main bearing journals. End play is controlled by the thrust washers that are located on the rear main bearing.

The timing gears are stamped with timing marks in order to ensure the correct assembly of the gears. When the No. 1 piston is at top center compression stroke, the teeth that are stamped on the crankshaft gear and the camshaft gear will be in alignment with the idler gear.

The crankshaft gear turns the idler gear which then turns the camshaft gear and the gear for the engine oil pump.

The fuel injection pump is mounted in the cylinder block. The fuel injection pump is operated by lobes on the camshaft. The fuel transfer pump is located on the right hand side of the cylinder block. The fuel transfer pump is also operated by lobes on the camshaft.

The fuel injection pump conforms to requirements for emissions. If any adjustments to the fuel injection pump timing and high idle are required you must refer to your Perkins distributoror your Perkins dealer. Some fuel injection pumps have mechanical governors that control the engine rpm. Some fuel injection pumps have a governor that is electrically controlled.

A gerotor oil pump is located in the center of the idler gear. The engine oil pump sends lubricating oil to the main oil gallery through a pressure relief valve and an engine oil filter. The rocker arms receive pressurized oil through an externally located oil line that runs from the main oil gallery to the cylinder head.

Coolant from the bottom of the radiator passes through the belt driven centrifugal water pump. The coolant is cooled by the radiator and the temperature is regulated by a water temperature regulator.

Engine efficiency, efficiency of emission controls, and engine performance depend on adherence to correct operation and maintenance recommendations. Engine performance and efficiency also depend on the use of recommended fuels, lubrication oils, and coolants. Refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” for more information on maintenance items.

Engine Specifications

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right side of the engine are determined from the flywheel end. The No. 1 cylinder is the front cylinder.

402D-05 Engine

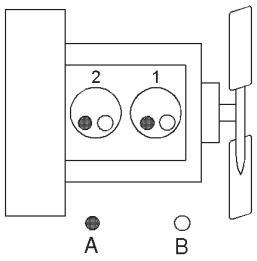

Illustration 13 g01108476

(A) Exhaust valves
(B) Inlet valves

Table 1

402D-05 Engine Specifications	
Maximum Operating Speed (rpm)	3600 rpm
Cylinders and Arrangement	In-Line two cylinder
Bore	67 mm (2.64 inch)
Stroke	72 mm (2.83 inch)
Displacement	0.507 L (30.939 in^3)
Aspiration	NA(1)
Compression Ratio	23.5:1
Firing Order	1-2
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

403D-07 Engine

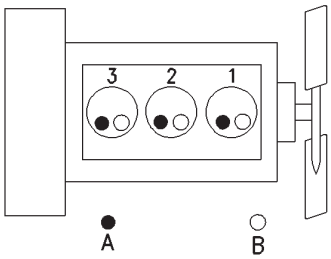

Illustration 14 g00852304

(A) Exhaust valves
(B) Inlet valves

Table 2

403D-07 Engine Specifications	
Maximum Operating Speed (rpm)	3600 rpm
Cylinders and Arrangement	In-Line three cylinder
Bore	67 mm (2.64 inch)
Stroke	72 mm (2.83 inch)
Displacement	0.762 L (46.500 in^3)
Aspiration	NA(1)
Compression Ratio	23.5:1
Firing Order	1-2-3
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

403D-11 Engine

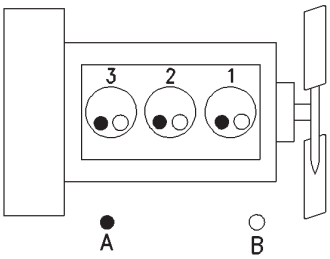

Illustration 15 g00852304

(A) Exhaust valves
(B) Inlet valves

Table 3

403D-11 Engine Specifications	
Maximum Operating Speed (rpm)	3600 rpm
Cylinders and Arrangement	In-Line three cylinder
Bore	77 mm (3.03 inch)
Stroke	81 mm (3.19 inch)
Displacement	1.131 L (69.018 in^3)
Aspiration	NA(1)
Compression Ratio	23:1
Firing Order	1-2-3
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

403D-15 Engine

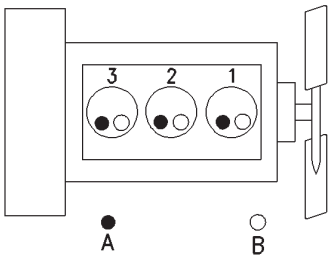

Illustration 16 g00852304

(A) Exhaust valves
(B) Inlet valves

Table 4

403D-15 Engine Specifications	
Maximum Operating Speed (rpm)	3000 rpm
Cylinders and Arrangement	In-Line three cylinder
Bore	84 mm (3.31 inch)
Stroke	90 mm (3.54 inch)
Displacement	1.496 L (91.291 in^3)
Aspiration	NA(1)
Compression Ratio	22.5:1
Firing Order	1-2-3
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

403D-15T Engine

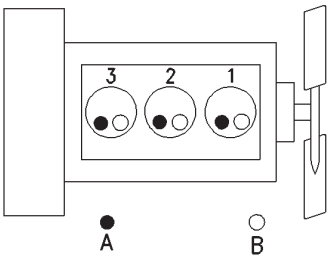

Illustration 17 g00852304

(A) Exhaust valves
(B) Inlet valves

Table 5

403D-15T Engine Specifications	
Maximum Operating Speed (rpm)	3000 rpm
Cylinders and Arrangement	In-Line three cylinder
Bore	84 mm (3.31 inch)
Stroke	90 mm (3.54 inch)
Displacement	1.496 L (91.291 in^3)
Aspiration	T(1)
Compression Ratio	22.5:1
Firing Order	1-2-3
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Turbocharged

403D-17 Engine

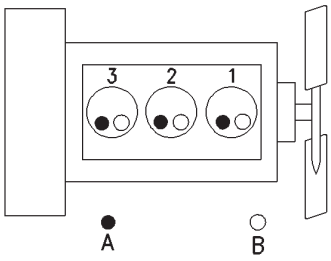

Illustration 18 g00852304

(A) Exhaust valves
(B) Inlet valves

Table 6

403D-17 Engine Specifications	
Maximum Operating Speed (rpm)	2600 rpm
Cylinders and Arrangement	In-Line three cylinder
Bore	84 mm (3.31 inch)
Stroke	100 mm (3.94 inch)
Displacement	1.66 L (101.3 in^3)
Aspiration	NA(1)
Compression Ratio	23.1:1
Firing Order	1-2-3
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

404D-15 Engine

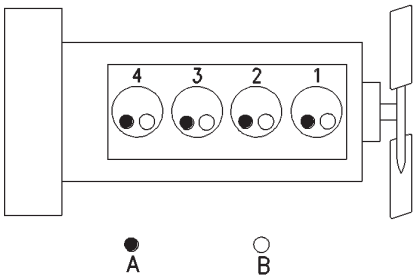

Illustration 19 g00296424

(A) Exhaust valves
(B) Inlet valves

Table 7

404D-15 Engine Specifications	
Maximum Operating Speed (rpm)	3000 rpm
Cylinders and Arrangement	In-Line four cylinder
Bore	77 mm (3.03 inch)
Stroke	81 mm (3.19 inch)
Displacement	1.508 L (92.024 in^3)
Aspiration	NA(1)
Compression Ratio	23.5:1
Firing Order	1-3-4-2
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

404D-22 Engine

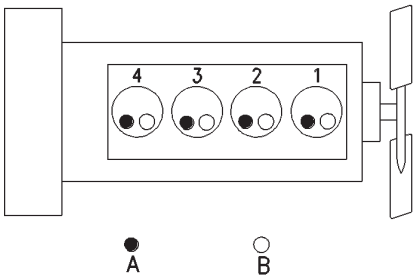

Illustration 20 g00296424

(A) Exhaust valves
(B) Inlet valves

Table 8

404D-22 Engine Specifications	
Maximum Operating Speed (rpm)	3000 rpm
Cylinders and Arrangement	In-Line four cylinder
Bore	84.0 mm (3.31 inch)
Stroke	100.0 mm (3.94 inch)
Displacement	2.216 L (135.229 in^3)
Aspiration	NA(1)
Compression Ratio	23.3:1
Firing Order	1-3-4-2
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Naturally Aspirated

404D-22T Engine

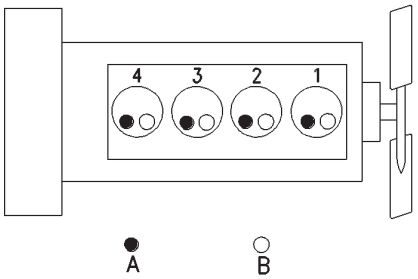

Illustration 21 g00296424

(A) Exhaust valves
(B) Inlet valves

Table 9

404D-22T Engine Specifications	
Maximum Operating Speed (rpm)	3000 rpm
Cylinders and Arrangement	In-Line four cylinder
Bore	84.0 mm (3.31 inch)
Stroke	100.0 mm (3.94 inch)
Displacement	2.216 L (135.229 in^3)
Aspiration	T(1)
Compression Ratio	23.5:1
Firing Order	1-3-4-2
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Turbocharged

404D-22TA Engine

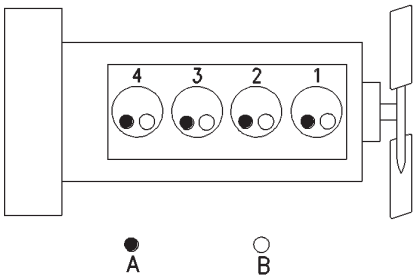

Illustration 22 g00296424

(A) Exhaust valves
(B) Inlet valves

Table 10

404D-22TA Engine Specifications	
Maximum Operating Speed (rpm)	2800 rpm
Cylinders and Arrangement	In-Line four cylinder
Bore	84.0 mm (3.31 inch)
Stroke	100.0 mm (3.94 inch)
Displacement	2.216 L (135.229 in^3)
Aspiration	TA(1)
Compression Ratio	23.5:1
Firing Order	1-3-4-2
Rotation that is viewed from the flywheel	Counterclockwise
Valve Lash Setting (Inlet)	0.20 mm (0.008 inch)
Valve Lash Setting (Exhaust)	0.20 mm (0.008 inch)
Injection	Indirect

(1) Turbocharged aftercooled

Product Identification Information

i03657510

Engine Identification

Perkins engines are identified by a serial number. This number is shown on a serial number plate that is mounted above the fuel injection pump on the right hand side of the engine block.

An example of an engine number is GP*****U000001T.

G _____ Engine family

P _____ Type of engine

***** _____ The list number of the engine

U _____ Country of manufacture

0 _____ The first digit is a production code.

00001 _____ Engine Serial Number

T _____ Year of Manufacture

Perkins dealers or Perkins distributors need all of these numbers in order to determine the components that were included with the engine. This permits accurate identification of replacement part numbers.

i02157258

Serial Number Plate

Illustration 23 g01094203

Typical serial number plate

The Serial Number Plate is located above the fuel injection pump on the right side of the cylinder block.

The following information is stamped on the Serial Number Plate: Engine serial number, Model and Arrangement number.

i02164876

Reference Numbers

Information for the following items may be needed to order parts. Locate the information for your engine. Record the information in the appropriate space. Make a copy of this list for a record. Keep the information for future reference.

Record for Reference

Engine Model _____

Engine Serial number _____

Engine Low Idle rpm _____

Engine Full Load rpm _____

Primary Fuel Filter _____

Water Separator Element _____

Secondary Fuel Filter Element _____

Lubrication Oil Filter Element _____

Auxiliary Oil Filter Element _____

Total Lubrication System Capacity _____

Total Cooling System Capacity _____

Air Cleaner Element _____

Fan Drive Belt _____

Alternator Belt

i06591372

Emissions Certification Film

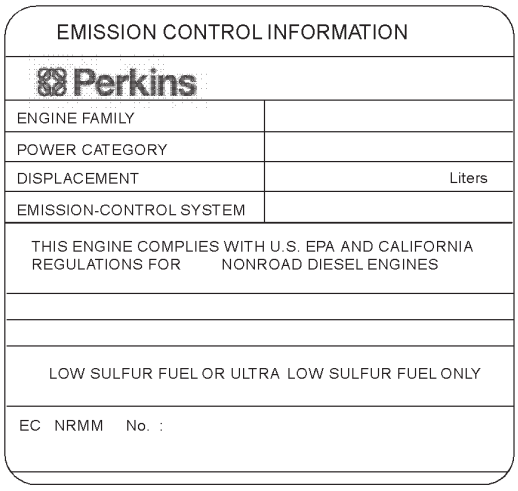

Illustration 24 g01478138

Typical example

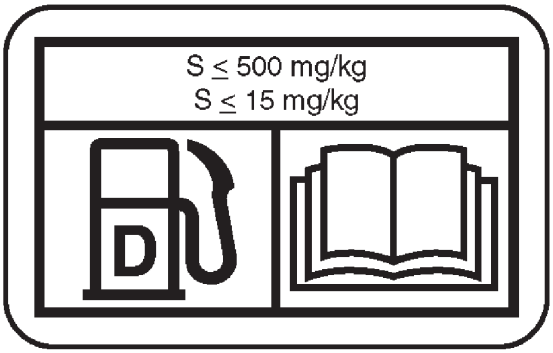

Illustration 25 g06038952

Typical example

Refer to illustration 25 . The equipment manufacturer must install the label to the equipment. This procedure is recommended by Perkins Shibaura Engines Limited. The label must be attached to the equipment near the fuel inlet to comply with the EPA regulations. The equipment manufacturer may install another fuel label.

Operation Section

Lifting and Storage

i02164186

Engine Lifting

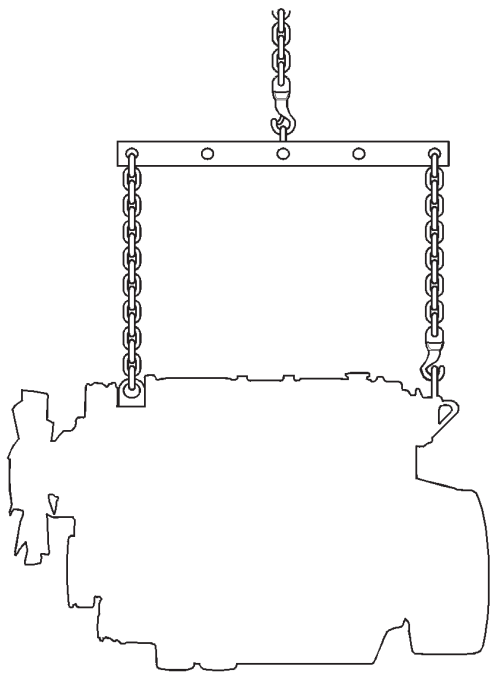

Illustration 26 g01097527

NOTICE
Never bend the eyebolts and the brackets. Only load the eyebolts and the brackets under tension. Remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90 degrees.

When it is necessary to remove a component at an angle, only use a link bracket that is properly rated for the weight.

Use a hoist to remove heavy components. Use an adjustable lifting beam to lift the engine. All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted.

Some removals require lifting the fixtures in order to obtain correct balance and safety.

To remove the engine ONLY, use the lifting eyes that are on the engine.

Lifting eyes are designed and installed for specific engine arrangements. Alterations to the lifting eyes and/or the engine make the lifting eyes and the lifting fixtures obsolete. If alterations are made, ensure that correct lifting devices are provided. Consult your Perkins dealer or your Perkins distributor for information regarding fixtures for correct engine lifting.

i02593735

Engine Storage

If the engine will not be started for several weeks, the lubricating oil will drain from the cylinder walls and from the piston rings. Rust can form on the cylinder walls. Rust on the cylinder walls will cause increased engine wear and a reduction in engine service life.

Lubrication System

To help prevent excessive engine wear, use the following guidelines:

Complete all of the lubrication recommendations that are listed in this Operation and Maintenance Manual, “Maintenance Interval Schedule” (Maintenance Section).

If an engine is out of operation and if use of the engine is not planned, special precautions should be made. If the engine will be stored for more than one month, a complete protection procedure is recommended.

Use the following guidelines :

- Completely clean the outside of the engine.
- Drain the fuel system completely and refill the system with preservative fuel. 1772204 POWERPART Lay-Up 1 can be mixed with the normal fuel in order to change the fuel into preservative fuel.
- If preservative fuel is not available, the fuel system can be filled with normal fuel. This fuel must be discarded at the end of the storage period together with the fuel filter elements.
- Operate the engine until the engine reaches normal operating temperature. Stop any leaks from fuel, lubricating oil or air systems. Stop the engine and drain the lubricating oil from the oil pan.
- Renew the canister(s) of the lubricating oil filter.

- Fill the oil pan to the Full Mark on the engine oil level gauge with new, clean lubricating oil. Add 1762811 POWERPART Lay-Up 2 to the oil in order to protect the engine against corrosion. If 1762811 POWERPART Lay-Up 2 is not available, use a preservative of the correct specification instead of the lubricating oil. If a preservative is used, this must be drained completely at the end of the storage period and the oil pan must be refilled to the correct level with normal lubricating oil.

Cooling System

To help prevent excessive engine wear, use the following guidelines:

NOTICE
Do not drain the coolant while the engine is still hot and the system is under pressure because dangerous hot coolant can be discharged.

If freezing temperatures are expected, check the cooling system for adequate protection against freezing. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” (Maintenance Section).

NOTICE
To prevent frost damage, ensure that all the coolant is removed from the engine. This is important if the system is drained after it has been flushed with water, or if an antifreeze solution too weak to protect the system from frost has been used.

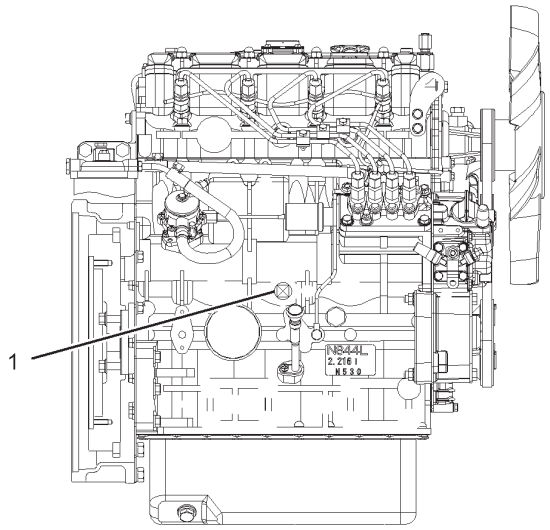

Illustration 27 g01298045
Typical example

1. Ensure that the vehicle is on level ground.

2. Remove the filler cap of the cooling system.

3. Remove the drain plug (1) from the side of the cylinder block in order to drain the engine. Ensure that the drain hole is not restricted.

4. Open the tap or remove the drain plug at the bottom of the radiator in order to drain the radiator. If the radiator does not have a tap or a drain plug, disconnect the hose at the bottom of the radiator.

5. Flush the cooling system with clean water.

6. Fit the drain plugs and the filler cap. Close the tap or connect the radiator hose.

7. Fill the cooling system with an approved antifreeze mixture because this gives protection against corrosion.

Note: Certain corrosion inhibitors could cause damage to some engine components. Contact the Service Department of Perkins for advice.

8. Operate the engine for a short period in order to circulate the lubricating oil and the coolant in the engine.

9. Disconnect the battery. Put the battery into safe storage in a fully charged condition. Before the battery is put into storage, protect the terminals against corrosion. 1734115 POWERPART Lay-Up 3 can be used on the terminals.

10. Clean the crankcase breather if one is installed. Seal the end of the pipe.

11. Remove the fuel injectors and spray 1762811 POWERPART Lay-Up 2 for one or two seconds into each cylinder bore with the piston at BDC.

12. Slowly rotate the crankshaft for one complete revolution and then replace the fuel injectors.

Induction System

- Remove the air filter assembly. If necessary, remove the pipes that are installed between the air filter assembly and the turbocharger. Spray 1762811 POWERPART Lay-Up 2 into the turbocharger. The duration of the spray is printed on the container. Seal the turbocharger with waterproof tape.

Exhaust System

- Remove the exhaust pipe. Spray 1762811 POWERPART Lay-Up 2 into the turbocharger. The duration of the spray is printed on the container. Seal the turbocharger with waterproof tape.

General Items

- If the lubricating oil filler is installed on the valve mechanism cover, remove the filler cap. If the lubricating oil filler cap is not installed on the valve mechanism cover, remove the valve mechanism cover. Spray 1762811 POWERPART Lay-Up 2 around the rocker shaft assembly. Replace the filler cap or the valve mechanism cover.
- Seal the vent of the fuel tank or the fuel filler cap with waterproof tape.
- Remove the alternator drive belts and put the drive belts into storage.
- In order to prevent corrosion, spray the engine with 1734115 POWERPART Lay-Up 3 . Do not spray the area inside the alternator.

When the engine protection has been completed in accordance with these instructions, this ensures that no corrosion will occur. Perkins are not responsible for damage which may occur when an engine is in storage after a period in service.

Your Perkins dealer or your Perkins distributor can assist in preparing the engine for extended storage periods.

Gauges and Indicators

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Gauges and Indicators

Your engine may not have the same gauges or all of the gauges that are described. For more information about the gauge package, see the OEM information.

Gauges provide indications of engine performance. Ensure that the gauges are in good working order. Determine the normal operating range by observing the gauges over a period of time.

Noticeable changes in gauge readings indicate potential gauge or engine problems. Problems may also be indicated by gauge readings that change even if the readings are within specifications. Determine and correct the cause of any significant change in the readings. Consult your Perkins dealer or your Perkins distributor for assistance.

NOTICE
If no oil pressure is indicated, STOP the engine. If maximum coolant temperature is exceeded, STOP the engine. Engine damage can result.

Engine Oil Pressure – The oil pressure should be greatest after a cold engine is started. The typical engine oil pressure with SAE10W30 is 207 to 413 kPa (30 to 60 psi) at rated rpm.

A lower oil pressure is normal at low idle. If the load is stable and the gauge reading changes, perform the following procedure:

1. Remove the load.

2. Reduce engine speed to low idle.

3. Check and maintain the oil level.

Jacket Water Coolant Temperature – Typical temperature range is 71 to 96°C (160 to 205°F). The maximum allowable temperature with the pressurized cooling system at 90 kPa (13 psi) is 110°C (230°F). Higher temperatures may occur under certain conditions. The water temperature reading may vary according to load. The reading should never exceed the boiling point for the pressurized system that is being used.

If the engine is operating above the normal range and steam becomes apparent, perform the following procedure:

1. Reduce the load and the engine rpm.

2. Inspect the cooling system for leaks.

3. Determine if the engine must be shut down immediately or if the engine can be cooled by reducing the load.

Tachometer – This gauge indicates engine speed (rpm). When the throttle control lever is moved to the full throttle position without load, the engine is running at high idle. The engine is running at the full load rpm when the throttle control lever is at the full throttle position with maximum rated load.

NOTICE
To help prevent engine damage, never exceed the high idle rpm. Overspeeding can result in serious damage to the engine. The engine can be operated at high idle without damage, but should never be allowed to exceed high idle rpm.

Ammeter – This gauge indicates the amount of charge or discharge in the battery charging circuit. Operation of the indicator should be to the right side of “0” (zero).

Fuel Level – This gauge indicates the fuel level in the fuel tank. The fuel level gauge operates when the “START/STOP” switch is in the “ON” position.

Service Hour Meter – The gauge indicates operating time of the engine.

Features and Controls

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Fuel Shutoff

The fuel shutoff solenoid is located on the fuel injection pump. When the fuel shutoff solenoid is activated, the solenoid moves the fuel rack to the “OFF” position.

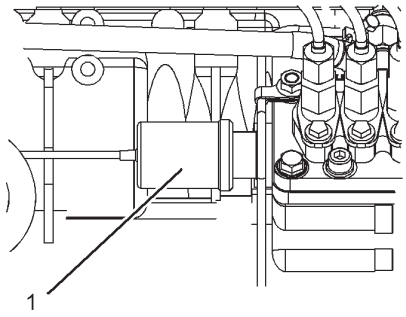

Illustration 28 g01305771

(1) Fuel shutoff solenoid

If an electronically controlled governor has been installed the governor operates the fuel rack in order to stop the engine.

Engine Starting

i02194223

Before Starting Engine

Before the engine is started, perform the required daily maintenance and any other periodic maintenance that is due. Refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” for more information.

- For the maximum service life of the engine, make a thorough inspection within the engine compartment before the engine is started. Look for the following items: oil leaks, coolant leaks, loose bolts and excessive dirt and/or grease. Remove any excess dirt and/or grease buildup. Repair any faults that were identified during the inspection.
- Inspect the cooling system hoses for cracks and for loose clamps.
- Inspect the alternator and accessory drive belts for cracks, breaks, and other damage.
- Inspect the wiring for loose connections and for worn wires or frayed wires.
- Check the fuel supply. Drain water from the water separator (if equipped). Open the fuel supply valve (if equipped).

NOTICE
All valves in the fuel return line must be open before and during engine operation to help prevent high fuel pressure. High fuel pressure may cause filter housing failure or other damage.

If the engine has not been started for several weeks, fuel may have drained from the fuel system. Air may have entered the filter housing. Also, when fuel filters have been changed, some air pockets will be trapped in the engine. In these instances, prime the fuel system. Refer to the Operation and Maintenance Manual, “Fuel System - Prime” for more information on priming the fuel system.

⚠ WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

- Do not start the engine or move any of the controls if there is a “DO NOT OPERATE” warning tag or similar warning tag attached to the start switch or to the controls.
- Ensure that the areas around the rotating parts are clear.
- All of the guards must be put in place. Check for damaged guards or for missing guards. Repair any damaged guards. Replace damaged guards and/or missing guards.
- Disconnect any battery chargers that are not protected against the high current drain that is created when the electric starting motor is engaged. Check electrical cables and check the battery for poor connections and for corrosion.
- Reset all of the shutoffs or alarm components (if equipped).
- Check the engine lubrication oil level. Maintain the oil level between the “ADD” mark and the “FULL” mark on the engine oil level gauge.
- Check the coolant level. Observe the coolant level in the header tank (if equipped). Maintain the coolant level to the “FULL” mark on the header tank.
- If the engine is not equipped with a header tank maintain the coolant level within 13 mm (0.5 inch) of the bottom of the filler pipe. If the engine is equipped with a sight glass, maintain the coolant level in the sight glass.
- Observe the air cleaner service indicator (if equipped). Service the air cleaner when the yellow diaphragm enters the red zone, or when the red piston locks in the visible position.
- Ensure that any equipment that is driven by the engine has been disengaged from the engine. Minimize electrical loads or remove any electrical loads.

i04053911

Before Starting Engine

Perform the required daily maintenance and other periodic maintenance before the engine is started. Inspect the engine compartment. This inspection can help prevent major repairs at a later date. Refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” for more information.

- Ensure that the engine has an adequate fuel supply.
- Open the fuel supply valve (if equipped).

If the engine has not been started for several weeks, fuel may have drained from the fuel system. Air may have entered the filter housing. Also, when fuel filters have been changed, some air pockets will be trapped in the engine. In these instances, prime the fuel system. Refer to the Operation and Maintenance Manual, “Fuel System - Prime” for more information on priming the fuel system. Also, check that the fuel specification is correct and that the fuel condition is correct. Refer to the Operation and Maintenance Manual, “Fuel Recommendations”.

⚠ WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

- Do not start the engine or move any of the controls if there is a “DO NOT OPERATE” warning tag or similar warning tag attached to the start switch or to the controls.
- Reset all of the shutoffs or alarm components.
- Ensure that any driven equipment has been disengaged. Minimize electrical loads or remove any electrical loads.

i06595330

Starting the Engine

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

Refer to the OEM manual for your type of controls. Use the following procedure to start the engine.

1. Move the throttle lever to the low idle position before you start the engine.

NOTICE
Do not operate the glow plugs for more than 60 seconds at one time. Damage to the glow plugs could occur.

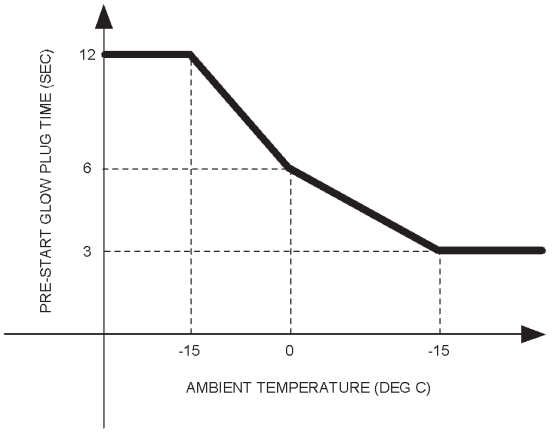

Illustration 29 g06038854

2. Turn the engine start switch to the HEAT position. Hold the engine start switch in the HEAT position for time shown in illustration 29 . This action will activate the glow plugs and aid in the starting of the engine.

NOTICE
Do not crank the engine for more than 30 seconds. Allow the electric starting motor to cool for two minutes before cranking the engine again.

3. When the glow plug indicator light is illuminated, turn the engine start switch to the START position and crank the engine.

4. When the engine starts, release the engine start switch.

5. Slowly move the throttle lever to the low idle position and allow the engine to idle. Refer to the Operation and Maintenance Manual, “After Starting Engine” topic.

Note: If the glow plug indicator light flashes rapidly for 2 to 3 seconds or fails to illuminate, a malfunction exists in the cold start system. Do not use ether or other starting fluids to start the engine.

6. If the engine does not start, release the engine start switch and allow the electric starting motor to cool. Then, repeat steps 2 through step 5.

7. Turn the engine start switch to the OFF position to stop the engine.

i02177935

Starting with Jump Start Cables

⚠ WARNING

Improper jump start cable connections can cause an explosion resulting in personal injury.

Prevent sparks near the batteries. Sparks could cause vapors to explode. Do not allow jump start cable ends to contact each other or the engine.

Note: If it is possible, first diagnose the reason for the starting failure. Make any necessary repairs. If the engine will not start only due to the condition of the battery, either charge the battery, or start the engine with jump start cables. The condition of the battery can be rechecked after the engine has been switched OFF.

NOTICE
Using a battery source with the same voltage as the electric starting motor. Use ONLY equal voltage for jump starting. The use of higher voltage will damage the electrical system.

Do not reverse the battery cables. The alternator can be damaged. Attach ground cable last and remove first.

When using an external electrical source to start the engine, turn the generator set control switch to the “OFF” position. Turn all electrical accessories OFF before attaching the jump start cables.

Ensure that the main power switch is in the OFF position before attaching the jump start cables to the engine being started.

1. Turn the start switch to the OFF position. Turn off all the engine's accessories.
2. Connect one positive end of the jump start cable to the positive cable terminal of the discharged battery. Connect the other positive end of the jump start cable to the positive cable terminal of the electrical source.
3. Connect one negative end of the jump start cable to the negative cable terminal of the electrical source. Connect the other negative end of the jump start cable to the engine block or to the chassis ground. This procedure helps to prevent potential sparks from igniting the combustible gases that are produced by some batteries.
4. Start the engine.
5. Immediately after the stalled engine is started, disconnect the jump start cables in reverse order.

After jump starting, the alternator may not be able to fully recharge batteries that are severely discharged. The batteries must be replaced or charged to the correct voltage with a battery charger after the engine is stopped. Many batteries which are considered unusable are still rechargeable. Refer to Operation and Maintenance Manual, “Battery - Replace” and Testing and Adjusting Manual, “Battery - Test”.

i01903609

After Starting Engine

Note: In temperatures from 0 to 60°C (32 to 140°F), the warm-up time is approximately three minutes. In temperatures below 0°C (32°F), additional warm-up time may be required.

When the engine idles during warm-up, observe the following conditions:

- Check for any fluid or for any air leaks at idle rpm and at one-half full rpm (no load on the engine) before operating the engine under load. This is not possible in some applications.
- Operate the engine at low idle until all systems achieve operating temperatures. Check all gauges during the warm-up period.

Note: Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

Engine Operation

i06015869

Engine Operation

Proper operation and maintenance are key factors in obtaining the maximum life and economy of the engine. If the directions in the Operation and Maintenance Manual are followed, costs can be minimized and engine service life can be maximized.

The engine can be operated at the rated rpm after the engine reaches operating temperature. The engine will reach normal operating temperature sooner during a low engine speed (rpm) and during a low-power demand. This procedure is more effective than idling the engine at no load. The engine should reach operating temperature in a few minutes.

Gauge readings should be observed and the data should be recorded frequently while the engine is operating. Comparing the data over time will help to determine normal readings for each gauge. Comparing data over time will also help detect abnormal operating developments. Significant changes in the readings should be investigated.

i02330149

Fuel Conservation Practices

The efficiency of the engine can affect the fuel economy. Perkins design and technology in manufacturing provides maximum fuel efficiency in all applications. Follow the recommended procedures in order to attain optimum performance for the life of the engine.

- Avoid spilling fuel.

Fuel expands when the fuel is warmed up. The fuel may overflow from the fuel tank. Inspect fuel lines for leaks. Repair the fuel lines, as needed.

- Be aware of the properties of the different fuels. Use only the recommended fuels.
- Avoid unnecessary idling.

Shut off the engine rather than idle for long periods of time.

- Observe the air cleaner service indicator frequently. Keep the air cleaner elements clean.
- Maintain the electrical systems.

One damaged battery cell will overwork the alternator. This will consume excess power and excess fuel.

- Ensure that the drive belts are correctly adjusted. The drive belts should be in good condition.
- Ensure that all of the connections of the hoses are tight. The connections should not leak.
- Ensure that the driven equipment is in good working order.
- Cold engines consume excess fuel. Utilize heat from the jacket water system and the exhaust system, when possible. Keep cooling system components clean and keep cooling system components in good repair. Never operate the engine without water temperature regulators. All of these items will help maintain operating temperatures.

Engine Stopping

i02334873

Stopping the Engine

NOTICE
Stopping the engine immediately after it has been working under load, can result in overheating and accelerated wear of the engine components.

Avoid accelerating the engine prior to shutting it down.

Avoiding hot engine shutdowns will maximize turbocharger shaft and bearing life.

Note: Individual applications will have different control systems. Ensure that the shutoff procedures are understood. Use the following general guidelines in order to stop the engine.

1. Remove the load from the engine. Reduce the engine speed (rpm) to low idle. Allow the engine to idle for five minutes in order to cool the engine.
2. Stop the engine after the cool down period according to the shutoff system on the engine and turn the ignition key switch to the OFF position. If necessary, refer to the instructions that are provided by the OEM.

i01903586

Emergency Stopping

NOTICE
Emergency shutoff controls are for EMERGENCY use ONLY. DO NOT use emergency shutoff devices or controls for normal stopping procedure.

The OEM may have equipped the application with an emergency stop button. For more information about the emergency stop button, refer to the OEM information.

Ensure that any components for the external system that support the engine operation are secured after the engine is stopped.

i03756631

After Stopping Engine

Note: Before you check the engine oil, do not operate the engine for at least 10 minutes in order to allow the engine oil to return to the oil pan.

- Check the crankcase oil level. Maintain the oil level between the “MIN” mark and the “MAX” mark on the engine oil level gauge.
- If necessary, perform minor adjustments. Repair any leaks and tighten any loose bolts.
- If the engine is equipped with a service hour meter, note the reading. Perform the maintenance that is in the Operation and Maintenance Manual, “Maintenance Interval Schedule”.
- Fill the fuel tank in order to help prevent accumulation of moisture in the fuel. Do not overfill the fuel tank.

NOTICE
Only use antifreeze/coolant mixtures recommended in the Refill Capacities and Recommendations topic that is in this Operation and Maintenance Manual. Failure to do so can cause engine damage.

- Allow the engine to cool. Check the coolant level.
- If freezing temperatures are expected, check the coolant for correct antifreeze protection. The cooling system must be protected against freezing to the lowest expected outside temperature. Add the correct coolant/water mixture, if necessary.
- Perform all required periodic maintenance on all driven equipment. This maintenance is outlined in the instructions from the OEM.

Cold Weather Operation

i05927231

Cold Weather Operation

Perkins Diesel Engines can operate effectively in cold weather. During cold weather, the starting and the operation of the diesel engine is dependent on the following items:

- The type of fuel that is used
- The viscosity of the engine oil
- The operation of the glow plugs
- Optional Cold starting aid
- Battery condition
- Ambient air temperature and altitude
- Parasitic load of the application
- Application hydraulic and transmission oil viscosities

This section will cover the following information:

- Potential problems that are caused by cold-weather operation
- Suggest steps which can be taken in order to minimize starting problems and operating problems when the ambient air temperature is between 0° to−40 °C (32° to 40 °F).

The operation and maintenance of an engine in freezing temperatures is complex . This complexity is because of the following conditions:

- Weather conditions
- Engine applications

Recommendations from your Perkins dealer or your Perkins distributor are based on past proven practices. The information that is contained in this section provides guidelines for cold-weather operation.

Hints for Cold Weather Operation

- If the engine will start, operate the engine until a minimum operating temperature of 81 °C (177.8 °F) is achieved. Achieving operating temperature will help prevent the intake valves and exhaust valves from sticking.
- The cooling system and the lubrication system for the engine do not lose heat immediately upon shutdown. This means that an engine can be shut down for a period of time, and the engine can still be ability to start readily.
- Install the correct specification of engine lubricant before the beginning of cold weather.
- Check all rubber parts (hoses, fan drive belts.) weekly.
- Check all electrical wiring and connections for any fraying or damaged insulation.
- Keep all batteries fully charged and warm.
- Fill the fuel tank at the end of each shift.
- Check the air cleaners and the air intake daily. Check the air intake more often when you operate in snow.
- Ensure that the glow plugs are in working order. Refer to Testing and Adjusting Manual, “Glow Plug - Test”.

⚠ WARNING

Personal injury or property damage can result from alcohol or starting fluids.

Alcohol or starting fluids are highly flammable and toxic and if improperly stored could result in injury or property damage.

⚠ WARNING

Do not use aerosol types of starting aids such as ether. Such use could result in an explosion and personal injury.

- For jump starting with cables in cold weather, refer to the Operation and Maintenance Manual, “Starting with Jump Start Cables.” for instructions.

Viscosity of the Engine Lubrication Oil

Correct engine oil viscosity is essential. Oil viscosity affects the amount of torque that is needed to crank the engine. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for the recommended viscosity of oil.

Recommendations for the Coolant

Provide cooling system protection for the lowest expected outside temperature. Refer to this Operation and Maintenance Manual, “Fluid Recommendations” for the recommended coolant mixture.

In cold weather, check the coolant often for the correct glycol concentration in order to ensure adequate freeze protection.

Engine Block Heaters

Engine block heaters (if equipped) heat the engine jacket water that surrounds the combustion chambers. This heat provides the following functions:

- Startability is improved.
- Warm up time is reduced.

An electric block heater can be activated once the engine is stopped. An effective block heater is typically a 1250/1500 W unit. Consult your Perkins dealer or your Perkins distributor for more information.

Idling the Engine

When idling after the engine is started in cold weather, increase the engine rpm from 1000 to 1200 rpm. This increase in RPM will warm up the engine more quickly. Maintaining an elevated low idle speed for extended periods will be easier with the installation of a hand throttle. The engine should not be “raced” in order to speed up the warm-up process.

While the engine is idling, the application of a light load (parasitic load) will assist in achieving the minimum operating temperature. The minimum operating temperature is 82 °C (179.6 °F).

Recommendations for Coolant Warm Up

Warm up an engine that has cooled below normal operating temperatures due to inactivity. The warm-up should be performed before the engine is returned to full operation. During operation in very cold temperature conditions, damage to engine valve mechanisms can result from engine operation for short intervals. This action can happen if the engine is started and the engine is stopped many times without being operated in order to warm up completely.

When the engine is operated below normal operating temperatures, fuel and oil are not completely burned in the combustion chamber. This fuel and oil causes soft carbon deposits to form on the valve stems. Generally, the deposits do not cause problems and the deposits are burned off during operation at normal engine operating temperatures.

When the engine is started and the engine is stopped many times without being operated in order to warm up completely, the carbon deposits become thicker. This action can cause the following problems:

- Free operation of the valves is prevented.
- Valves become stuck.
- Pushrods may become bent.
- Other damage to valve train components can result.

For this reason, when the engine is started, the engine must be operated until the coolant temperature is 71 °C (160 °F) minimum. Carbon deposits on the valve stems will be kept at a minimum. The free operation of the valves and the valve components will be maintained.

In addition, the engine must be thoroughly warmed in order to keep other engine parts in better condition and the service life of the engine will be generally extended. Lubrication will be improved. There will be less acid and less sludge in the oil. This lubrication will provide longer service life for the engine bearings, the piston rings, and other parts. However, limit unnecessary idle time to 10 minutes in order to reduce wear and unnecessary fuel consumption.

The Water Temperature Regulator and Insulated Heater Lines

The engine is equipped with a water temperature regulator. When the engine coolant is below the correct operating temperature, jacket water circulates through the engine cylinder block and into the engine cylinder head. The coolant then returns to the cylinder block via an internal passage that bypasses the valve of the coolant temperature regulator. This system ensures that coolant flows around the engine under cold operating conditions. The water temperature regulator begins to open when the engine jacket water has reached the correct minimum operating temperature. As the jacket water coolant temperature rises above the minimum operating temperature the water temperature regulator opens further allowing more coolant through the radiator to dissipate excess heat.

The progressive opening of the water temperature regulator operates the progressive closing of the bypass passage between the cylinder block and head. This system ensures maximum coolant flow to the radiator in order to achieve maximum heat dissipation.

Note: Perkins discourages the use of all air flow restriction devices such as radiator shutters. Restriction of the air flow can result in the following: high exhaust temperatures, power loss, excessive fan usage and reduction in fuel economy.

A cab heater is beneficial in very cold weather. The feed from the engine and the return lines from the cab should be insulated in order to reduce heat loss to the outside air.

Insulating the Air Inlet and Engine Compartment

When temperatures below −18 °C (−0 °F) will be frequently encountered, an air cleaner inlet that is located in the engine compartment may be specified. An air cleaner that is located in the engine compartment may also minimize the entry of snow into the air cleaner. Also, heat that is rejected by the engine helps to warm the intake air.

Additional heat can be retained around the engine by insulating the engine compartment.

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Fuel and the Effect from Cold Weather

Note: Only use grades of fuel that are recommended by Perkins. Refer to this Operation and Maintenance Manual, “Fluid Recommendations”.

Properties of the diesel fuel can have a significant effect on the engine cold start capability. Critical to the low temperature properties of diesel fuel is the acceptability for the minimum ambient temperature the engine is expected to see in operation. Following properties are used to define fuels low temperature capability:

- Cloud point
- Pour point
- Cold Filter Plugging Point (CFPP)

The cloud point of the fuel is the temperature at which waxes naturally found in diesel fuel begins to form crystals. The cloud point of the fuel must be below lowest ambient temperature to prevent filters from plugging.

CFPP is a temperature at which a particular fuel will pass through a standardized filtration device. The CFPP gives an estimate of the lower operability temperature of fuel.

Pour point is the last temperature before the fuel flow stops and waxing of the fuel will start.

Be aware of these properties when diesel fuel is purchased. Consider the average ambient air temperature for the engines application. Engines that are fueled in one climate may not operate well if the engines are shipped to colder climate. Problems can result due to changes in temperature.

Before troubleshooting for low power or for poor performance in the winter, check the fuel for waxing.

The following components can provide a means of minimizing fuel waxing problems in cold weather:

- Fuel heaters, which may be an OEM option
- Fuel line insulation, which may be an OEM option

Winter and arctic grades of diesel fuel are available in the countries and territories with severe winters. For more information refer to the Operation and Maintenance Manual, “Cold Weather Operation”

Another important fuel property which can affect cold start and operation of diesel engine is cetane number. For more information refer to the Operation and Maintenance Manual, “Fluid Recommendations”.

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Fuel Related Components in Cold Weather

Fuel Tanks

Condensation can form in partially filled fuel tanks. Top off the fuel tanks after you operate the engine.

Fuel tanks should contain some provision for draining water and sediment from the bottom of the tanks. Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe.

Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Drain the water and sediment from any fuel storage tank at the following intervals: weekly, oil changes and refueling of the fuel tank. This will help prevent water and/or sediment from being pumped from the fuel storage tank and into the engine fuel tank.

Fuel Filters

It is possible that a primary fuel filter is installed between the fuel tank and the engine fuel inlet. After you change the fuel filter, always prime the fuel system in order to remove air bubbles from the fuel system. Refer to the Operation and Maintenance Manual in the Maintenance Section for more information on priming the fuel system.

The micron rating and the location of a primary fuel filter is important in cold weather operation. The primary fuel filter and the fuel supply line are the most common components that are affected by cold fuel.

Fuel Heaters

Note: The OEM may equip the application with fuel heaters. If this is the case, disconnect an electric type of fuel heater in warm weather in order to prevent overheating of the fuel. If the type of fuel heater is a heat exchanger, the OEM should have included a bypass for warm weather. Ensure that the bypass is operational during warm weather in order to prevent overheating of the fuel.

For more information about fuel heaters (if equipped), refer to the OEM information.

Maintenance Section

Refill Capacities

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Refill Capacities

Lubrication System

The refill capacities for the engine crankcase reflect the approximate capacity of the crankcase or sump plus standard oil filters. Auxiliary oil filter systems will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter. Refer to the Operation and Maintenance Manual, “Maintenance Section” for more information on Lubricant Specifications.

402D-05 Engine

Table 11

402D-05 Engine Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	1.61 L (1.7 qt)	2.01 L (2.1 qt)
Total Lubrication System(2)		

(1) These values are the approximate capacities for the crankcase oil sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

403D-07 Engine

Table 12

403C-07 Engine Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	2.35 L (2.5 qt)	3.05 L (3.2 qt)
Total Lubrication System(2)		

(continued)

(Table 12, contd)

(1) These values are the approximate capacities for the crankcase oil sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

403D-11 Engine

Table 13

403D-11 Engine Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	3.4 L (3.6 qt)	4.4 L (4.6494 qt)
Total Lubrication System(2)		

(1) These values are the approximate capacities for the crankcase oil sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

403D-15 and 403D-15T Engines

Table 14

403D-15 and 403D-15T Engines Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	4.5 L (4.8 qt)	6 L (6.3 qt)
Total Lubrication System(2)		

(1) These values are the approximate capacities for the crankcase oil sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

403D-17 Engine

Table 15

403D-17 Engine Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	4.5 L (4.8 qt)	6 L (6.3 qt)
Total Lubrication System(2)		

(1) These values are the approximate capacities for the crankcase oil sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

404D-15 Engine

Table 16

404D-15 Engine Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	3.9 L (4.1211 qt)	5.6 L (5.9175 qt)
Total Lubrication System(2)		

(1) These values are the approximate capacities for the crankcase oil sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

404D-22, 404D-22T and 404D-22TA Engines

Table 17

404D-22, 404D-22T and 404D-22TA Engines Refill Capacities		
Compartment or System	**Minimum**	**Maximum**
Crankcase Oil Sump(1)	8.9 L (9.4 qt)	10.6 L (11.2 qt)
Total Lubrication System(2)		

(continued)

(Table 17, contd)

(1) More than one style of sump may be used on these engines. Use these values to estimate the refill capacity. Use the engine oil level gauge to fill the engine to the correct oil level. Record the result in this table. These values are the approximate capacities for the Crankcase Oil Sump which includes the standard factory installed oil filters. Engines with auxiliary oil filters will require additional oil. Refer to the OEM specifications for the capacity of the auxiliary oil filter.
(2) The Total Lubrication System includes the capacity for the Crankcase Oil Sump plus the capacity of factory installed oil filters and other filters added to the lubrication system. Enter the value for the capacity of the Total Lubrication System in this row.

Cooling System

To maintain the cooling system, the Total Cooling System capacity must be known. The approximate capacity is for the engine cooling system. External System capacities will vary among applications. Refer to the OEM specifications for the External System capacity. This capacity information will be needed in order to determine the amount of coolant that is required for the Total Cooling System.

402D-05 Engine

Table 18

402D-05 Engine Refill Capacities		
Compartment or System	**Liters**	**Quarts**
Engine Only	1.1	1.2
External System Per OEM(1)		
Total Cooling System(2)		

(1) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.
(2) The Total Cooling System capacity includes the capacity of the Engine plus the External System. Enter the value for the capacity of the Total Cooling System in this row.

403D-07 Engine

Table 19

403D-07 Engine Refill Capacities		
Compartment or System	**Liters**	**Quarts**
Engine Only	1.2	1.3
External System Per OEM(1)		
Total Cooling System(2)		

(1) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.
(2) The Total Cooling System capacity includes the capacity of the Engine plus the External System. Enter the value for the capacity of the Total Cooling System in this row.

403D-11 Engine

Table 20

403D-11 Engine Refill Capacities		
Compartment or System	**Liters**	**Quarts**
Engine Only	1.9	2.0
External System Per OEM(1)		
Total Cooling System(2)		

(1) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.
(2) The Total Cooling System capacity includes the capacity of the Engine plus the External System. Enter the value for the capacity of the Total Cooling System in this row.

403D-15 and 403D-15T Engines

Table 21

403D-15 and 403D-15TEngines Refill Capacities		
Compartment or System	**Liters**	**Quarts**
Engine Only	2.6	2.7
External System Per OEM(1)		
Total Cooling System(2)		

(1) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.
(2) The Total Cooling System capacity includes the capacity of the Engine plus the External System. Enter the value for the capacity of the Total Cooling System in this row.

404D-15 Engine

Table 22

404D-15 Engine Refill Capacities		
Compartment or System	**Liters**	**Quarts**
Engine Only	2.4	2.5
External System Per OEM(1)		
Total Cooling System(2)		

(1) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.
(2) The Total Cooling System capacity includes the capacity of the Engine plus the External System. Enter the value for the capacity of the Total Cooling System in this row.

404D-22, 404D-22T and 404D-22TA Engines

Table 23

404D-22,404D-22T and 404D-22TA Engines Refill Capacities		
Compartment or System	**Liters**	**Quarts**
Engine Only	3.6	3.8
External System Per OEM(1)		
Total Cooling System(2)		

(1) The External System includes a radiator or an expansion tank with the following components: heat exchanger and piping. Refer to the OEM specifications. Enter the value for the capacity of the External System in this row.
(2) The Total Cooling System capacity includes the capacity for the Engine plus the External System. Enter the value for the capacity of the Total Cooling System in this row.

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Fluid Recommendations
(Fuel Specification)

- **Glossary**
- ISO International Standards Organization
- ASTM American Society for Testing and Materials
- HFRR High Frequency Reciprocating Rig for Lubricity testing of diesel fuels
- FAME Fatty Acid Methyl Esters
- CFR Co-ordinating Fuel Research
- LSD Low Sulfur Diesel
- ULSD Ultra Low Sulfur Diesel
- RME Rape Methyl Ester
- SME Soy Methyl Ester
- EPA Environmental Protection Agency of the United States

General Information

NOTICE
Every attempt is made to provide accurate, up to date information. By use of this document you agree that Perkins Engines Company Limited is not responsible for errors or omissions.

NOTICE
These recommendations are subject to change without notice. Contact your local Perkins distributor for the most up to date recommendations.

Diesel Fuel Requirements

Satisfactory engine performance is dependent on the use of a good quality fuel. The use of a good quality fuel will give the following results: long engine life and acceptable exhaust emissions levels. The fuel must meet the minimum requirements that are stated in tables 24 , 25 and 26 .

NOTICE
The footnotes are a key part of the Perkins Specification for Distillate Diesel Fuel Table. Read ALL of the footnotes.

Table 24

Perkins Specification for Distillate Diesel Fuel (1)				
Property	**UNITS**	**Requirements**	**“ASTM”Test**	**“ISO”Test**
Aromatics	%Volume	35% maximum	D1319	“ISO”3837
Ash	%Weight	0.02% maximum	D482	“ISO”6245
Carbon Residue on 10% Bottoms	%Weight	0.35% maximum	D524	“ISO”4262
Cetane Number (2)	-	40 minimum	D613/D6890	“ISO”5165
Cloud Point	°C	The cloud point must not exceed the lowest expected ambient temperature.	D2500	“ISO”3015
Copper Strip Corrosion	-	No. 3 maximum	D130	“ISO”2160
Density at 15 °C (59 °F) (3)	Kg / M ^{3}	801 minimum and 876 maximum	No equivalent test	“ISO 3675 ”“ISO 12185”
Distillation	°C	10% at 282 °C (539.6 °F) maximum 90% at 360 °C (680 °F) maximum	D86	“ISO”3405
Flash Point	°C	legal limit	D93	“ISO”2719
Thermal Stability	-	Minimum of 80% reflectance after aging for 180 minutes at 150 °C (302 °F)	D6468	No equivalent test
Pour Point	°C	6 °C (42.8 °F) minimum below ambient temperature	D97	“ISO”3016
Sulfur (1) (4)	%mass	The level of sulfur that is in the fuel is controlled by emissions regulations. Refer to Tables 25 and 26 for more information.	D5453/D26222	“ISO 20846 ”“ISO 20884”

(continued)

(Table 24, contd)

Kinematic Viscosity (5)	"MM"2"/S (cSt)"	The viscosity of the fuel that is delivered to the fuel injection pump. "1.4 minimum/ 4.5 maximum"	D445	"ISO"3405
Water and sediment	% weight	0.1% maximum	D1796	"ISO"3734
Water	% weight	0.1% maximum	D1744	No equivalent test
Sediment	% weight	0.05% maximum	D473	"ISO"3735
Gums and Resins (6)	mg/100mL	10 mg per 100 mL maximum	D381	"ISO"6246
Lubricity corrected wear scar diameter at 60 °C (140 °F). (7)	mm	0.46 maximum	D6079	"ISO"12156-1

(1) This specification includes the requirements for Ultra Low Sulfur Diesel (ULSD). ULSD fuel will have ≤ 15 ppm (0.0015%) sulfur. Refer to "ASTM D5453", "ASTM D2622", or "ISO 20846, ISO 20884" test methods. This specification includes the requirements for Low Sulfur Diesel (LSD). LSD fuel will have ≤500 ppm (0.05%) sulfur. Refer to following:"ASTM 5453, ASTM D2622", "ISO 20846" and "ISO 20884 test methods". Refer to Tables 25 and 26 .

(2) A fuel with a higher cetane number is recommended in order to operate at a higher altitude or in cold weather.

(3) "Via standards tables, the equivalent API gravity for the minimum density of 801 kg / m^3 (kilograms per cubic meter) is 45 and for the maximum density of 876 kg / m^3 is 30".

(4) Regional regulations, national regulations or international regulations can require a fuel with a specific sulfur limit. Consult all applicable regulations before selecting a fuel for a given engine application. Perkins fuel systems and engine components can operate on high sulfur fuels in territories that are non-emissions regulated. Fuel sulfur levels affect exhaust emissions. High sulfur fuels also increase the potential for corrosion of internal components. Fuel sulfur levels above 0.5% may significantly shorten the oil change interval. For additional information, refer to this manual, "Fluid recommendations (General lubricant Information)".

(5) The values of the fuel viscosity are the values as the fuel is delivered to the fuel injection pumps. Fuel should also meet the minimum viscosity requirement and the fuel should meet the maximum viscosity requirements at 40 °C (104 °F) of either the "ASTM D445" test method or the "ISO 3104" test method. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to 4.5 cSt at the fuel injection pump.

(6) Follow the test conditions and procedures for gasoline (motor).

(7) The lubricity of a fuel is a concern with low sulfur and ultra low sulfur fuel. To determine the lubricity of the fuel, use the "ISO 12156-1 or ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

NOTICE
Operating with fuels that do not meet the Perkins recommendations can cause the following effects: Starting difficulty, poor combustion, deposits in the fuel injectors, reduced service life of the fuel system, deposits in the combustion chamber and reduced service life of the engine.

Diesel Fuel Characteristics

Perkins Recommendation

Cetane Number

Fuel that has a high cetane number will give a shorter ignition delay. This will produce a better ignition quality. Cetane numbers are derived for fuels against proportions of cetane and heptamethylnonane in the standard CFR engine. Refer to "ISO 5165" for the test method.

Cetane numbers in excess of 45 are normally expected from current diesel fuel. However, a cetane number of 40 may be experienced in some territories. The United States of America is one of the territories that can have a low cetane value. A minimum cetane value of 40 is required during average starting conditions. A higher cetane value may be required for operations at high altitudes or in cold weather operations.

Fuel with a low cetane number can be the root cause of problems during cold start.

Viscosity

Viscosity is the property of a liquid of offering resistance to shear or flow. Viscosity decreases with increasing temperature. This decrease in viscosity follows a logarithmic relationship for normal fossil fuel. The common reference is to kinematic viscosity. This is the quotient of the dynamic viscosity that is divided by the density. The determination of kinematic viscosity is normally by readings from gravity flow viscometers at standard temperatures. Refer to "ISO 3104" for the test method.

The viscosity of the fuel is significant because fuel serves as a lubricant for the fuel system components. Fuel must have sufficient viscosity in order to lubricate the fuel system in both extremely cold temperatures and extremely hot temperatures. If the kinematic viscosity of the fuel is lower than 1.4 cSt at the fuel injection pump damage to the fuel injection pump can occur. This damage can be excessive scuffing and seizure. Low viscosity may lead to difficult hot restarting, stalling and loss of performance. High viscosity may result in seizure of the pump.

Perkins recommends kinematic viscosities of 1.4 and 4.5 mm2/sec that is delivered to the fuel injection pump.

Density

Density is the mass of the fuel per unit volume at a specific temperature. This parameter has a direct influence on engine performance and a direct influence on emissions. This determines the heat output from a given injected volume of fuel. This is generally quoted in the following kg/m at 15 °C (59 °F).

Perkins recommends a value of density of 841 kg/m in order to obtain the correct power output. Lighter fuels are acceptable but these fuels will not produce the rated power.

Sulfur

The level of sulfur is governed by emissions legislations. Regional regulation, national regulations or international regulations can require a fuel with a specific sulfur limit. The sulfur content of the fuel and the fuel quality must comply with all existing local regulations for emissions.

Tables 25 and 26 list the guidelines for the correct sulfur level for specific territories. Consult all applicable regulations before selecting the fuel for a given engine application.

Table 25

Territory	Fuel Requirements from 2007		
EPA	Low Sulfur (500 ppm) maximum		
EC	Sulfur/Power	Low sulfur (300 ppm) maximum for less than or equal to 19 kW	Sulphur (1000 ppm) maximum for greater than 19 kW
	Models	402D-05 and 403D-07	403D-11, 403D-15, 403D-15T, 403D-17, 404D-15. 404D-22, 404D-22T and 404D-22TA
Non-Regulated Territories	Sulfur limit of less than 4000 ppm		

Table 26

Territory	Fuel Requirements from 2010		
EPA	Ultra Low Sulfur (15 ppm) maximum		
EC	Sulfur/Power	Ultra Low sulphur (10 ppm) maximum for less than or equal to 37 kW	Low sulphur (300 ppm) maximum for greater than 37 kW
	Models	402D-05, 403D-07, 403D-11, 403D-15, 403D-15T, 403D-17, 404D-15	404D-22, 404D-22T and 404D-22TA
Non Regulated Territories	Sulfur limit of less than 4000 ppm		

By using the test methods “ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884”, the content of sulfur in low sulfur diesel (LSD) fuel must be below 500 PPM 0.05%. By using the test methods “ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884”, the content of sulfur in ultra low sulfur (ULSD) fuel must be below 15 PPM 0.0015%. The lubricity of these fuels must not exceed wear scar diameter of 0.46 mm (0.0181 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to “ISO 12156-1 ”.

In some parts of the world and for some applications, high sulfur fuels above 0.5% by mass might only be available. Fuel with very high sulfur content can cause engine wear. High sulfur fuel will have a negative impact on emissions of particulates. High sulfur fuel can be used provided that the local emissions legislation will allow the use. High sulfur fuel can be used in countries that do not regulate emissions.

When only high sulfur fuels are available, it will be necessary that high alkaline lubricating oil is used in the engine or that the lubricating oil change interval is reduced. Refer to this Operation and Maintenance Manual, “Fliud Recommendations (Genernal Lubrication Information)” for information on sulfur in fuel.

Lubricity

This is the capability of the fuel to prevent pump wear. The fluid's lubricity describes the ability of the fluid to reduce the friction between surfaces that are under load. This ability reduces the damage that is caused by friction. Fuel injection systems rely on the lubricating properties of the fuel. Until fuel sulfur limits were mandated, the fuel's lubricity was generally believed to be a function of fuel viscosity.

The lubricity has particular significance to the current low viscosity fuel, low sulfur fuel and low aromatic fossil fuel. These fuels are made in order to meet stringent exhaust emissions. A test method for measuring the lubricity of diesel fuels has been developed and the test is based on the HFRR method that is operated at 60 °C (140 °F). Refer to “ISO 12156 part 1 and CEC document F06-A-96” for the test method.

Lubricity wear scar diameter of 0.46 mm (0.0181 inch) MUST NOT be exceeded. The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to “ISO 12156-1 ”.

Fuel additives can enhance the lubricity of a fuel. Contact your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can make recommendations for additives to use and for the proper level of treatment. Refer to “Fuel Additive” for more information.

Distillation

This is an indication of the mixture of different hydrocarbons in the fuel. A high ratio of light weight hydrocarbons can affect the characteristics of combustion.

Classification of the Fuels

Diesel engines have the ability to burn a wide variety of fuels. These fuels are divided into four general groups: Ref to table 27

Table 27

Fuel Groups	Classification	
Group 1	Preferred fuels	Full life of the Product
Group 2	Permissible fuels	These fuels MAY cause reduced engine life and performance
Group 3	Aviation fuels	These fuels WILL cause reduced engine life and performance
Group 4	Biodiesel	

Group 1 Specifications (Preferred Fuels)

This group of fuel specifications is considered acceptable:

- EN590 DERV Grade A, B, C, E, F, Class, 0, 1, 2, 3 and 4
- “ASTM D975”, Grade 2D S15 and Grade 2D S500
- “JIS K2204 Grades 1,2,3 and Special Grade 3” This grade of fuel must meet the minimum lubricity requirements that are stated in table 24 .
- “BS2869 Class A2” Off-Highway Gas Oil Red Diesel

Note: BS2869 can only be used if the sulfur level meets the specifications that are listed in tables 25 and 26 . An analysis of a sample of fuel must be conducted in order to check the sulfur level.

Note: The use of LSD fuel and the use of ULSD fuel is acceptable provided that the fuels meet the minimum requirements that are stated in tables 24 , 25 and 26 . The lubricity of these fuels must not exceed wear scar diameter of 0.46 mm (0.0181 inch) . The lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to “ISO 12156-1 ”. By using the test methods “ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884”, the content of sulfur in LSD fuel must be below 500 PPM 0.05%. By using the test methods “ASTM D5453, ASTM D2622, or ISO 20846 ISO 20884”, the content of sulfur in ULSD fuel must be below 15 PPM 0.0015%.

Group 2 Specifications (Permissible Fuels)

This group of fuel specifications is considered acceptable, but these fuels MAY reduce the engine life and performance.

- “ASTM D975”, Grade 1D S15 and Grade 1D S500
- “JP7 (MIL-T-38219)”
- “NATO F63”

Note: JP7 and NATO F63 can only be used if the sulfur level meets the specifications that are listed in tables 25 and 26 . An analysis of a sample of fuel must be conducted in order to check the sulfur level.

Group 3 Specifications (Aviation Fuels)

This group of fuel specification must be used only with the appropriate fuel additive. This fuel WILL reduce engine life and performance.

- “NATO F34 (MIL-DTL-83133E)”
- “NATO F35 (MIL-DTL-83133E)”
- “NATO JP8 (MIL-DTL-83133E)”
- “NATO F-44 (MIL-DTL-5624U)”
- “NATO JP5 (MIL-DTL-5624U)”
- “Jet A (ASTM D1655)”
- “Jet A1 (ASTM D1655)”

Note: All the above fuels can ONLY be used if the sulfur level meets the specifications that are listed in tables 25 and 26 . An analysis of a sample of fuel must be conducted in order to check the sulfur level.

Note: These fuels are only acceptable provided that these fuels are used with an appropriate fuel additive. These fuels must meet the requirements that are stated in tables 24 , 25 and 26 . Fuel samples should be analyzed for the compliance. These fuels MUST NOT exceed lubricity wear scar diameter of 0.46 mm (0.0181 inch). The fuel lubricity test must be performed on a HFRR, operated at 60 °C (140 °F). Refer to “ISO 12156-1 ”. Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

Group 4 Biodiesel

Biodiesel is a fuel that can be defined as mono-alkyl esters of fatty acids. Biodiesel is a fuel that can be made from a variety of feedstock. The most commonly available biodiesel in europe is Rape Methyl Ester (REM). This biodiesel is derived from rapeseed oil. Soy Methyl Ester (SME) is the most common biodiesel in the United States. This biodiesel is derived from soybean oil. Soybean oil or rapeseed oil are the primary feedstocks. These fuels are together known as Fatty Acid Methyl Esters (FAME).

Raw pressed vegetable oils are NOT acceptable for use as a fuel in any concentration in compression engines. Without esterification, these oils gel in the crankcase and the fuel tank. These fuels may not be compatible with many of the elastomers that are used in engines that are manufactured today. In original forms, these oils are not suitable for use as a fuel in compression engines. Alternate base stocks for biodiesel may include animal tallow, waste cooking oils, or a variety of other feedstocks. In order to use any of the products that are listed as fuel, the oil must be esterified.

Note: Engines that are manufactured by Perkins are certified by use of the prescribed Environmental Protection Agency (EPA) and European Certification fuels. Perkins does not certify engines on any other fuel. The user of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer and allowed by the EPA and other appropriate regulatory agencies.

Recommendation for the use of biodiesel

The neat biodiesel must conform to “EN14214” or “ASTM D675” regulations. A maximum of 10% mixture of biodiesel can be used in mineral diesel fuel. The mineral diesel fuel must conform to “EN590”, “ASTM D975” or “BS2869 Grade A2” regulations.

In North America, biodiesel and mixtures of biodiesel must be purchased from the BQ9000 authorized manufacturers and BQ9000 certified distributors.

In other areas of the world, the use of biodiesel that is authorized and certified by an appropriate biodiesel quality body is required.

Note: When biodiesel, or any blend of biodiesel is used, the user has the responsibility for obtaining the proper local exemptions, regional exemptions, and/or national exemptions that are required for the use of biodiesel in any Perkins engine that is regulated by emissions standards. Biodiesel that meets “EN14214” is acceptable. The biodiesel must be blended with an acceptable distillate diesel fuel at the maximum stated percentages. However, the following operational recommendations must be followed:

- The oil change interval can be affected by the use of biodiesel. Use Services Oil Analysis in order to monitor the condition of the engine oil. Use Services Oil Analysis also in order to determine the oil change interval that is optimum.
- Confirm that biodiesel is acceptable for use with the manufacturer of the fuel filters.
- In a comparison of distillate fuels to biodiesel, biodiesel provides less energy per gallon by 5% to 7%. Do NOT change the engine rating in order to compensate for the power loss. This will help avoid engine problems when the engine is converted back to 100 percent distillate diesel fuel.
- The compatibility of the elastomers with biodiesel is being monitored. The condition of seals and hoses should be monitored regularly.
- Biodiesel may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attainment of the proper cloud point for the fuel.
- Biodiesel has poor oxidation stability, which can result in long term problems in the storage of biodiesel. The poor oxidation stability may accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because these engines operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.

- Biodiesel is a fuel that can be made from a variety of feedstock. The feedstock that is used can affect the performance of the product. Two of the characteristics of the fuel that are affected are cold flow and oxidation stability. Contact your fuel supplier for guidance.
- Biodiesel or biodiesel blends are not recommended for engines that will operate occasionally. This is due to poor oxidation stability. If the user is prepared to accept some risk, then limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles
- Biodiesel is an excellent medium for microbial contamination and growth. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. The use of conventionalanti-microbial additives and the effectiveness of conventional anti-microbial additives in biodiesel is not known. Consult your supplier of fuel and additive for assistance.
- Care must be taken in order to remove water from fuel tanks. Water accelerates microbial contamination and growth. When biodiesel is compared to distillate fuels, water is naturally more likely to exist in the biodiesel.

Fuel for Cold Weather Operation

The European standard “EN590” contains climate dependant requirements and a range of options. The options can be applied differently in each country. There are 5 classes that are given to arctic climates and severe winter climates. 0, 1, 2, 3 and 4.

Fuel that complies with “EN590” CLASS 4 can be used at temperatures as low as −44 °C (−47.2 °F). Refer to “EN590” for a detailed discretion of the physical properties of the fuel.

The diesel fuel “ASTM D975 Grade 1-D S15 or S500” that is used in the united states of america may be used in very cold temperatures that are below −18 °C (−0.4 °F).

In extreme cold ambient conditions, you may also use fuels that are listed in the table 28 . These fuels are intended to be used in temperatures that can be as low as −54 °C (−65.2 °F).

Table 28

Light Distillate Fuels (1)	
Specification	Grade
“MIL-DTL-5624U”	JP-5

(continued)

(Table 28, contd)

“MIL-DTL-83133E”	JP-8
“ASTM D1655”	Jet-A-1

(1) The use of these fuels is acceptable with an appropriate fuel additive and the fuels must meet minimum requirements that are stated in Tables 24 , 25 and 26 . Fuel samples should be analyzed for the compliance. Fuels MUST NOT exceed 0.46 mm lubricity wear scar diameter that is tested on a HFFR . The test must be performed at 60 °C. Refer to “ISO 12156-1”. Fuels must have minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump. Fuel cooling may be required in order to maintain minimum viscosity of 1.4 centistokes that is delivered to the fuel injection pump.

⚠ WARNING

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or the fuel tank. Alcohol or gasoline must not be used in order to dilute diesel fuel. Failure to follow this instruction may result in death or personal injury.

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in tables 24 , 25 and 26 . To ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are stated in the tables 24 , 25 and 26 .

Fuel Additive

Supplemental diesel fuel additives are not generally recommended. This is due to potential damage to the fuel system or the engine. Your fuel supplier or the fuel manufacturer will add the appropriate supplemental diesel fuel additives.

Perkins recognizes the fact that additives may be required in some special circumstances. Fuel additives need to be used with caution. The additive may not be compatible with the fuel. Some additives may precipitate. This action causes deposits in the fuel system. The deposits may cause seizure. Some additives may be corrosive, and some additives may be harmful to the elastomers in the fuel system. Some additives may raise fuel sulfur levels above the maximum that is allowed by the EPA or the other regulatory agencies. Contact your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can recommend the appropriate fuel additive and the correct level of treatment.

Note: For the best results, your fuel supplier should treat the fuel when additives are required. The treated fuel must meet the requirements that are stated in tables 24 , 25 and 26 .

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Fluid Recommendations (Coolant Specifications)

General Coolant Information

NOTICE
Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

NOTICE
If the engine is to be stored in, or shipped to an area with below freezing temperatures, the cooling system must be either protected to the lowest outside temperature or drained completely to prevent damage.

NOTICE
Frequently check the specific gravity of the coolant for proper freeze protection or for anti-boil protection.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

Many engine failures are related to the cooling system. The following problems are related to cooling system failures: Overheating, leakage of the water pump and plugged radiators or heat exchangers.

These failures can be avoided with correct cooling system maintenance. Cooling system maintenance is as important as maintenance of the fuel system and the lubrication system. Quality of the coolant is as important as the quality of the fuel and the lubricating oil.

Coolant is normally composed of three elements: Water, additives and glycol.

Water

Water is used in the cooling system in order to transfer heat.

Distilled water or deionized water is recommended for use in engine cooling systems.

DO NOT use the following types of water in cooling systems: Hard water, softened water that has been conditioned with salt and sea water.

If distilled water or deionized water is not available, use water with the properties that are listed in Table 29 .

Table 29

Acceptable Water	
Property	**Maximum Limit**
Chloride (Cl)	40 mg/L
Sulfate (SO_4)	100 mg/L
Total Hardness	170 mg/L
Total Solids	340 mg/L
Acidity	pH of 5.5 to 9.0

For a water analysis, consult one of the following sources:

- Local water utility company
- Agricultural agent
- Independent laboratory

Additives

Additives help to protect the metal surfaces of the cooling system. A lack of coolant additives or insufficient amounts of additives enable the following conditions to occur:

- Corrosion
- Formation of mineral deposits
- Rust
- Scale
- Foaming of the coolant

Many additives are depleted during engine operation. These additives must be replaced periodically.

Additives must be added at the correct concentration. Overconcentration of additives can cause the inhibitors to drop out-of-solution. The deposits can enable the following problems to occur:

- Formation of gel compounds
- Reduction of heat transfer

- Leakage of the water pump seal
- Plugging of radiators, coolers, and small passages

Glycol

Glycol in the coolant helps to provide protection against the following conditions:

- Boiling
- Freezing
- Cavitation of the water pump

For optimum performance, Perkins recommends a 1:1 mixture of a water/glycol solution.

Note: Use a mixture that will provide protection against the lowest ambient temperature.

Note: 100 percent pure glycol will freeze at a temperature of −23 °C (−9 °F).

Most conventional antifreezes use ethylene glycol. Propylene glycol may also be used. In a 1:1 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling. See Tables 30 and 31 .

Table 30

Ethylene Glycol	
Concentration	**Freeze Protection**
50 Percent	−36 °C (−33 °F)
60 Percent	−51 °C (−60 °F)

NOTICE
Do not use propylene glycol in concentrations that exceed 50 percent glycol because of propylene glycol's reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing.

Table 31

Propylene Glycol	
Concentration	**Freeze Protection**
50 Percent	−29 °C (−20 °F)

To check the concentration of glycol in the coolant, measure the specific gravity of the coolant.

Coolant Recommendations

- ELC Extended Life Coolant
- SCA Supplement Coolant Additive
- ASTM American Society for Testing and Materials

The following two coolants are used in Perkins diesel engines:

Preferred – Perkins ELC

Acceptable – A commercial heavy-duty antifreeze that meets “ASTM D4985” specifications

NOTICE
Do not use a commercial coolant/antifreeze that only meets the ASTM D3306 specification. This type of coolant/antifreeze is made for light automotive applications.

Perkins recommends a 1:1 mixture of water and glycol. This mixture of water and glycol will provide optimum heavy-duty performance as a antifreeze. This ratio may be increased to 1:2 water to glycol if extra freezing protection is required.

Note: A commercial heavy-duty antifreeze that meets “ASTM D4985” specifications MAY require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

In stationary engine applications and marine engine applications that do not require anti-boil protection or freeze protection, a mixture of SCA and water is acceptable. Perkins recommends a six percent to eight percent concentration of SCA in those cooling systems. Distilled water or deionized water is preferred. Water which has the recommended properties may be used.

Table 32

Coolant Service Life	
Coolant Type	**Service Life**
Perkins ELC	6,000 Service Hours or Three Years
Commercial Heavy-Duty Antifreeze that meets “ASTM D4985”	3000 Service Hours or Two Years
Perkins POWERPART SCA	3000 Service Hours or Two Years
Commercial SCA and Water	3000 Service Hours or Two Years

ELC

Perkins provides ELC for use in the following applications:

- Heavy-duty spark ignited gas engines
- Heavy-duty diesel engines
- Automotive applications

The anti-corrosion package for ELC is different from the anti-corrosion package for other coolants. ELC is an ethylene glycol base coolant. However, ELC contains organic corrosion inhibitors and antifoam agents with low amounts of nitrite. Perkins ELC has been formulated with the correct amount of these additives in order to provide superior corrosion protection for all metals in engine cooling systems.

ELC is available in a 1:1 premixed cooling solution with distilled water. The Premixed ELC provides freeze protection to −36 °C (−33 °F). The Premixed ELC is recommended for the initial fill of the cooling system. The Premixed ELC is also recommended for topping off the cooling system.

Containers of several sizes are available. Consult your Perkins distributor for the part numbers.

ELC Cooling System Maintenance

Correct additions to the Extended Life Coolant

NOTICE
Use only Perkins products for pre-mixed or concentrated coolants.

Mixing Extended Life Coolant with other products reduces the Extended Life Coolant service life. Failure to follow the recommendations can reduce cooling system components life unless appropriate corrective action is performed.

In order to maintain the correct balance between the antifreeze and the additives, you must maintain the recommended concentration of ELC. Lowering the proportion of antifreeze lowers the proportion of additive. This will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

NOTICE
Do not use a conventional coolant to top-off a cooling system that is filled with Extended Life Coolant (ELC).

Do not use standard supplemental coolant additive (SCA).

When using Perkins ELC, do not use standard SCA's or SCA filters.

ELC Cooling System Cleaning

Note: If the cooling system is already using ELC, cleaning agents are not required to be used at the specified coolant change interval. Cleaning agents are only required if the system has been contaminated by the addition of some other type of coolant or by cooling system damage.

Clean water is the only cleaning agent that is required when ELC is drained from the cooling system.

Before the cooling system is filled, the heater control (if equipped) must be set to the HOT position. Refer to the OEM in order to set the heater control. After the cooling system is drained and the cooling system is refilled, operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture in order to fill the system to the specified level.

Changing to Perkins ELC

To change from heavy-duty antifreeze to the Perkins ELC, perform the following steps:

NOTICE
Care must be taken to ensure that all fluids are contained during performance of inspection, maintenance, testing, adjusting and the repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant into a suitable container.
2. Dispose of the coolant according to local regulations.
3. Flush the system with clean water in order to remove any debris.
4. Use Perkins cleaner to clean the system. Follow the instruction on the label.
5. Drain the cleaner into a suitable container. Flush the cooling system with clean water.
6. Fill the cooling system with clean water and operate the engine until the engine is warmed to 49° to 66°C (120° to 150°F).

NOTICE
Incorrect or incomplete flushing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all the signs of the cleaning agent are gone.

7. Drain the cooling system into a suitable container and flush the cooling system with clean water.

Note: The cooling system cleaner must be thoroughly flushed from the cooling system. Cooling system cleaner that is left in the system will contaminate the coolant. The cleaner may also corrode the cooling system.

8. Repeat Steps 6 and 7 until the system is completely clean.

9. Fill the cooling system with the Perkins Premixed ELC.

ELC Cooling System Contamination

NOTICE
Mixing ELC with other products reduces the effectiveness of the ELC and shortens the ELC service life. Use only Perkins Products for premixed or concentrate coolants. Failure to follow these recommendations can result in shortened cooling system component life.

ELC cooling systems can withstand contamination to a maximum of ten percent of conventional heavy-duty antifreeze or SCA. If the contamination exceeds ten percent of the total system capacity, perform ONE of the following procedures:

- Drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Flush the system with clean water. Fill the system with the Perkins ELC.
- Drain a portion of the cooling system into a suitable container according to local regulations. Then, fill the cooling system with premixed ELC. This should lower the contamination to less than 10 percent.
- Maintain the system as a conventional Heavy-Duty Coolant. Treat the system with an SCA. Change the coolant at the interval that is recommended for the conventional Heavy-Duty Coolant.

Commercial Heavy-Duty Antifreeze and SCA

NOTICE
Commercial Heavy-Duty Coolant which contains Amine as part of the corrision protection system must not be used.

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the correct operating temperature. Cooling system problems can develop without water temperature regulators.

Check the antifreeze (glycol concentration) in order to ensure adequate protection against boiling or freezing. Perkins recommends the use of a refractometer for checking the glycol concentration.

Perkins engine cooling systems should be tested at 500 hour intervals for the concentration of SCA.

Additions of SCA are based on the results of the test. An SCA that is liquid may be needed at 500 hour intervals.

Refer to Table 33 for part numbers and for quantities of SCA.

Table 33

Perkins Liquid SCA	
Part Number	**Quantity**
21825735	10

Adding the SCA to Heavy-Duty Coolant at the Initial Fill

Commercial heavy-duty antifreeze that meets “ASTM D4985” specifications MAY require an addition of SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

Use the equation that is in Table 34 to determine the amount of Perkins SCA that is required when the cooling system is initially filled.

Table 34

Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill
V × 0.045 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 35 is an example for using the equation that is in Table 34 .

Table 35

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.045	0.7 L (24 oz)

Adding The SCA to The Heavy-Duty Coolant For Maintenance

Heavy-duty antifreeze of all types REQUIRE periodic additions of an SCA.

Test the antifreeze periodically for the concentration of SCA. For the interval, refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” (Maintenance Section). Test the concentration of SCA.

Additions of SCA are based on the results of the test. The size of the cooling system determines the amount of SCA that is needed.

Use the equation that is in Table 36 to determine the amount of Perkins SCA that is required, if necessary:

Table 36

Equation For Adding The SCA To The Heavy-Duty Coolant For Maintenance
V × 0.014 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 37 is an example for using the equation that is in Table 36 .

Table 37

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant For Maintenance		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.014	0.2 L (7 oz)

Cleaning the System of Heavy-Duty Antifreeze

Perkins cooling system cleaners are designed to clean the cooling system of harmful scale and corrosion. Perkins cooling system cleaners dissolve mineral scale, corrosion products, light oil contamination and sludge.

- Clean the cooling system after used coolant is drained or before the cooling system is filled with new coolant.
- Clean the cooling system whenever the coolant is contaminated or whenever the coolant is foaming.

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Fluid Recommendations

General Lubricant Information

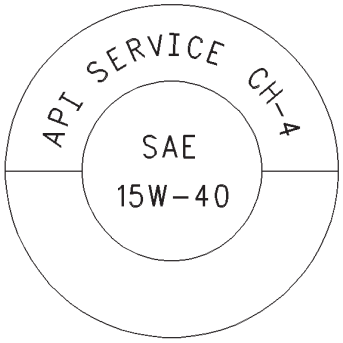
Because of government regulations regarding the certification of exhaust emissions from the engine, the lubricant recommendations must be followed.

Engine Manufacturers Association (EMA) Oils

The “Engine Manufacturers Association Recommended Guideline on Diesel Engine Oil” is recognized by Perkins. For detailed information about this guideline, see the latest edition of EMA publication, “EMA DHD -1”.

API Oils

The Engine Oil Licensing and Certification System by the American Petroleum Institute (API) is recognized by Perkins. For detailed information about this system, see the latest edition of the “API publication No. 1509”. Engine oils that bear the API symbol are authorized by API.



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Typical API symbol

Diesel engine oils CC, CD, CD-2, and CE have not been API authorized classifications since January 1, 1996. Table 38 summarizes the status of the classifications.

Table 38

API Classifications	
Current	**Obsolete**
CF-4, CG-4, CH-4	CE
CF	CC, CD
CF-2(1)	CD-2(1)

(1) The classifications CD-2 and American Petroleum Institute CF-2 are for two-cycle diesel engines. Perkins does not sell engines that utilize CD-2 and API CF-2 oils.

Terminology

Certain abbreviations follow the nomenclature of "SAE J754". Some classifications follow "SAE J183" abbreviations, and some classifications follow the "EMA Recommended Guideline on Diesel Engine Oil". In addition to Perkins definitions, there are other definitions that will be of assistance in purchasing lubricants. Recommended oil viscosities can be found in this publication, "Fluid Recommendations/ Engine Oil" topic (Maintenance Section).

Engine Oil

Commercial Oils

The performance of commercial diesel engine oils is based on American Petroleum Institute (API) classifications. These API classifications are developed in order to provide commercial lubricants for a broad range of diesel engines that operate at various conditions.

Only use commercial oils that meet the following classifications:

- EMA DHD-1 multigrade oil (preferred oil)
- API CH-4 multigrade oil (preferred oil)
- ACEAE5

In order to make the correct choice of a commercial oil, refer to the following explanations:

EMA DHD-1 – The Engine Manufacturers Association (EMA) has developed lubricant recommendations as an alternative to the API oil classification system. DHD-1 is a Recommended Guideline that defines a level of oil performance for these types of diesel engines: high speed, four stroke cycle, heavy-duty and light duty. DHD-1 oils may be used in Perkins engines when the following oils are recommended: API CH-4, API CG-4 and API CF-4. DHD-1 oils are intended to provide superior performance in comparison to API CG-4 and API CF-4.

DHD-1 oils will meet the needs of high performance Perkins diesel engines that are operating in many applications. The tests and the test limits that are used to define DHD-1 are similar to the new API CH-4 classification. Therefore, these oils will also meet the requirements for diesel engines that require low emissions. DHD-1 oils are designed to control the harmful effects of soot with improved wear resistance and improved resistance to plugging of the oil filter. These oils will also provide superior control of piston deposits for engines with either two-piece steel pistons or aluminum pistons.

All DHD-1 oils must complete a full test program with the base stock and with the viscosity grade of the finished commercial oil. The use of "API Base Oil Interchange Guidelines" are not appropriate for DHD-1 oils. This feature reduces the variation in performance that can occur when base stocks are changed in commercial oil formulations.

DHD-1 oils are recommended for use in extended oil change interval programs that optimize the life of the oil. These oil change interval programs are based on oil analysis. DHD-1 oils are recommended for conditions that demand a premium oil. Your Perkins dealer or your Perkins distributor has the specific guidelines for optimizing oil change intervals.

API CH-4 – API CH-4 oils were developed in order to meet the requirements of the new high performance diesel engines. Also, the oil was designed to meet the requirements of the low emissions diesel engines. API CH-4 oils are also acceptable for use in older diesel engines and in diesel engines that use high sulfur diesel fuel. API CH-4 oils may be used in Perkins engines that use API CG-4 and API CF-4 oils. API CH-4 oils will generally exceed the performance of API CG-4 oils in the following criteria: deposits on pistons, control of oil consumption, wear of piston rings, valve train wear, viscosity control and corrosion.

Three new engine tests were developed for the API CH-4 oil. The first test specifically evaluates deposits on pistons for engines with the two-piece steel piston. This test (piston deposit) also measures the control of oil consumption. A second test is conducted with moderate oil soot. The second test measures the following criteria: wear of piston rings, wear of cylinder liners and resistance to corrosion. A third new test measures the following characteristics with high levels of soot in the oil: wear of the valve train, resistance of the oil in plugging the oil filter and control of sludge.

In addition to the new tests, API CH-4 oils have tougher limits for viscosity control in applications that generate high soot. The oils also have improved oxidation resistance. API CH-4 oils must pass an additional test (piston deposit) for engines that use aluminum pistons (single piece). Oil performance is also established for engines that operate in areas with high sulfur diesel fuel.

All of these improvements allow the API CH-4 oil to achieve optimum oil change intervals. API CH-4 oils are recommended for use in extended oil change intervals. API CH-4 oils are recommended for conditions that demand a premium oil. Your Perkins dealer or your Perkins distributor has specific guidelines for optimizing oil change intervals.

Some commercial oils that meet the API classifications may require reduced oil change intervals. To determine the oil change interval, closely monitor the condition of the oil and perform a wear metal analysis.

NOTICE
Failure to follow these oil recommendations can cause shortened engine service life due to deposits and/or excessive wear.

Total Base Number (TBN) and Fuel Sulfur Levels for Diesel Engines

The Total Base Number (TBN) for an oil depends on the fuel sulfur level. For engines that use distillate fuel, the minimum TBN of the new oil must be 10 times the fuel sulfur level. The TBN is defined by "ASTM D2896". The minimum TBN of the oil is 5 regardless of fuel sulfur level. Illustration 31 demonstrates the TBN.

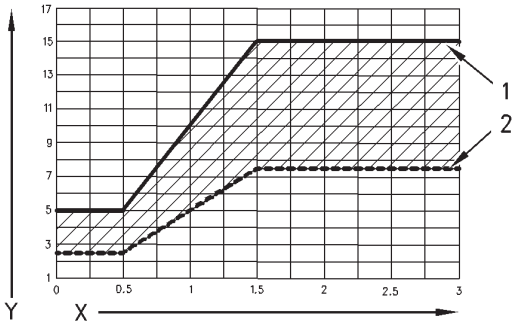

Illustration 31 g00799818

(Y) TBN by "ASTM D2896"
(X) Percentage of fuel sulfur by weight
(1) TBN of new oil
(2) Change the oil when the TBN deteriorates to 50 percent of the original TBN.

Use the following guidelines for fuel sulfur levels that exceed 1.5 percent:

- Choose an oil with the highest TBN that meets one of these classifications: EMA DHD-1 and API CH-4.
- Reduce the oil change interval. Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis.

Excessive piston deposits can be produced by an oil with a high TBN. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

NOTICE
Operating diesel engines with fuel sulphur levels over 0.5 percent will require shortened oil change intervals in order to help maintain adequate wear protection.

Table 39

Percentage of Sulfur in the fuel	Oil change interval
Lower than 0.5	Normal
0.5 to 1.0	0.75 of normal
Greater than 1.0	0.50 of normal

Lubricant Viscosity Recommendations

The correct SAE viscosity grade of oil is determined by the minimum ambient temperature during cold engine start-up, and the maximum ambient temperature during engine operation.

Refer to Table 40 (minimum temperature) in order to determine the required oil viscosity for starting a cold engine.

Refer to Table 40 (maximum temperature) in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Generally, use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

Table 40

Engine Oil Viscosity		
EMA LRG-1 API CH-4 Viscosity Grade	Ambient Temperature	
	Minimum	Maximum
SAE 0W20	−40 °C (−40 °F)	10 °C (50 °F)
SAE 0W30	−40 °C (−40 °F)	30 °C (86 °F)
SAE 0W40	−40 °C (−40 °F)	40 °C (104 °F)
SAE 5W30	−30 °C (−22 °F)	30 °C (86 °F)
SAE 5W40	−30 °C (−22 °F)	40 °C (104 °F)
SAE 10W30	−20 °C (−4 °F)	40 °C (104 °F)
SAE 15W40	−10 °C (14 °F)	50 °C (122 °F)

Synthetic Base Stock Oils

Synthetic base oils are acceptable for use in these engines if these oils meet the performance requirements that are specified for the engine.

Synthetic base oils generally perform better than conventional oils in the following two areas:

- Synthetic base oils have improved flow at low temperatures especially in arctic conditions.
- Synthetic base oils have improved oxidation stability especially at high operating temperatures.

Some synthetic base oils have performance characteristics that enhance the service life of the oil. Perkins does not recommend the automatic extending of the oil change intervals for any type of oil.

Re-refined Base Stock Oils

Re-refined base stock oils are acceptable for use in Perkins engines if these oils meet the performance requirements that are specified by Perkins. Re-refined base stock oils can be used exclusively in finished oil or in a combination with new base stock oils. The US military specifications and the specifications of other heavy equipment manufacturers also allow the use of re-refined base stock oils that meet the same criteria.

The process that is used to make re-refined base stock oil should adequately remove all wear metals that are in the used oil and all the additives that are in the used oil. The process that is used to make re-refined base stock oil generally involves the process of vacuum distillation and hydrotreating the used oil. Filtering is adequate for the production of high quality, re-refined base stock oil.

Lubricants for Cold Weather

When an engine is started and an engine is operated in ambient temperatures below −20 °C (−4 °F), use multigrade oils that are capable of flowing in low temperatures.

These oils have lubricant viscosity grades of SAE 0W or SAE 5W.

When an engine is started and operated in ambient temperatures below −30 °C (−22 °F), use a synthetic base stock multigrade oil with an 0W viscosity grade or with a 5W viscosity grade. Use an oil with a pour point that is lower than −50 °C (−58 °F).

The number of acceptable lubricants is limited in cold weather conditions. Perkins recommends the following lubricants for use in cold weather conditions:

First Choice – Use oil with an EMA DHD-1 Recommended Guideline. Use a CH-4 oil that has an API license. The oil should be either SAE 0W20, SAE 0W30, SAE 0W40, SAE 5W30, or SAE 5W40 lubricant viscosity grade.

Second Choice – Use an oil that has a CH-4 additive package. Although the oil has not been tested for the requirements of the API license, the oil must be either SAE 0W20, SAE 0W30, SAE 0W40, SAE 5W30, or SAE 5W40.

NOTICE
Shortened engine service life could result if second choice oils are used.

Aftermarket Oil Additives

Perkins does not recommend the use of aftermarket additives in oil. It is not necessary to use aftermarket additives in order to achieve the engine's maximum service life or rated performance. Fully formulated, finished oils consist of base oils and of commercial additive packages. These additive packages are blended into the base oils at precise percentages in order to help provide finished oils with performance characteristics that meet industry standards.

There are no industry standard tests that evaluate the performance or the compatibility of aftermarket additives in finished oil. Aftermarket additives may not be compatible with the finished oil's additive package, which could lower the performance of the finished oil. The aftermarket additive could fail to mix with the finished oil. This could produce sludge in the crankcase. Perkins discourages the use of aftermarket additives in finished oils.

To achieve the best performance from a Perkins engine, conform to the following guidelines:

- Select the correct oil, or a commercial oil that meets the “EMA Recommended Guideline on Diesel Engine Oil” or the recommended API classification.
- See the appropriate “Lubricant Viscosities” table in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine. Use new oil and install a new oil filter.
- Perform maintenance at the intervals that are specified in the Operation and Maintenance Manual, “Maintenance Interval Schedule”.

Oil analysis

Some engines may be equipped with an oil sampling valve. If oil analysis is required the oil sampling valve is used to obtain samples of the engine oil. The oil analysis will complement the preventive maintenance program.

The oil analysis is a diagnostic tool that is used to determine oil performance and component wear rates. Contamination can be identified and measured through the use of the oil analysis. The oil analysis includes the following tests:

- The Wear Rate Analysis monitors the wear of the engine's metals. The amount of wear metal and type of wear metal that is in the oil is analyzed. The increase in the rate of engine wear metal in the oil is as important as the quantity of engine wear metal in the oil.
- Tests are conducted in order to detect contamination of the oil by water, glycol or fuel.

- The Oil Condition Analysis determines the loss of the oil's lubricating properties. An infrared analysis is used to compare the properties of new oil to the properties of the used oil sample. This analysis allows technicians to determine the amount of deterioration of the oil during use. This analysis also allows technicians to verify the performance of the oil according to the specification during the entire oil change interval.

Maintenance Recommendations

i03751181

System Pressure Release

Coolant System

⚠ WARNING

Pressurized system: Hot coolant can cause serious burn. To open cap, stop engine, wait until radiator is cool. Then loosen cap slowly to relieve the pressure.

To relieve the pressure from the coolant system, turn off the engine. Allow the cooling system pressure cap to cool. Remove the cooling system pressure cap slowly in order to relieve pressure.

Fuel System

To relieve the pressure from the fuel system, turn off the engine.

High Pressure Fuel Lines (If Equipped)

⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

The high pressure fuel lines are the fuel lines that are between the high pressure fuel pump and the high pressure fuel manifold and the fuel lines that are between the fuel manifold and cylinder head. These fuel lines are different from fuel lines on other fuel systems.

This is because of the following differences:

- The high pressure fuel lines are constantly charged with high pressure.
- The internal pressures of the high pressure fuel lines are higher than other types of fuel system.

Before any service or repair is performed on the engine fuel lines, perform the following tasks:

1. Stop the engine.

2. Wait for ten minutes.

Do not loosen the high pressure fuel lines in order to remove air pressure from the fuel system.

Engine Oil

To relieve pressure from the lubricating system, turn off the engine.

i03751203

Welding on Engines with Electronic Controls

NOTICE
Because the strength of the frame may decrease, some manufacturers do not recommend welding onto a chassis frame or rail. Consult the OEM of the equipment or your Perkins dealer regarding welding on a chassis frame or rail.

Correct welding procedures are necessary in order to avoid damage to the engine's ECM, sensors, and associated components. When possible, remove the component from the unit and then weld the component. If removal of the component is not possible, the following procedure must be followed when you weld on a unit that is equipped with a Perkins Electronic Engine. The following procedure is considered to be the safest procedure to weld on a component. This procedure should provide a minimum risk of damage to electronic components.

NOTICE
Do not ground the welder to electrical components such as the ECM or sensors. Improper grounding can cause damage to the drive train, the bearings, hydraulic components, electrical components, and other components.

Do not ground the welder across the centerline of the package. Improper grounding could cause damage to the bearings, the crankshaft, the rotor shaft, and other components.

Clamp the ground cable from the welder to the component that will be welded. Place the clamp as close as possible to the weld. This will help reduce the possibility of damage.

Note: Perform the welding in areas that are free from explosive hazards.

1. Stop the engine. Turn the switched power to the OFF position.

2. Disconnect the negative battery cable from the battery. If a battery disconnect switch is provided, open the switch.

3. Disconnect the J1/P1 and J2/P2 connectors from the ECM. Move the harness to a position that will not allow the harness to accidentally move back and make contact with any of the ECM pins.

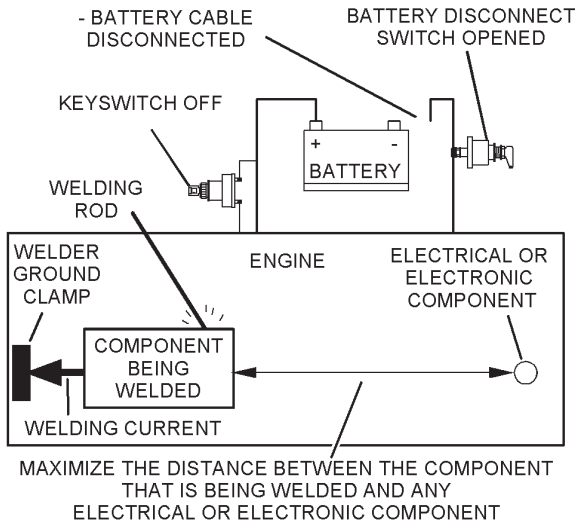

Illustration 32 g01143634

4. Connect the welding ground cable directly to the part that will be welded. Place the ground cable as close as possible to the weld in order to reduce the possibility of welding current damage to bearings, hydraulic components, electrical components, and ground straps.

Note: If electrical/electronic components are used as a ground for the welder, or electrical/electronic components are located between the welder ground and the weld, current flow from the welder could severely damage the component.

5. Protect the wiring harness from welding debris and spatter.

6. Use standard welding practices to weld the materials.

i04890317

Maintenance Interval Schedule

When Required

Daily

Every 50 Service Hours or Weekly

Every 250 Service Hours or 6 Months

Every 500 Service Hours

Every 500 Service Hours or 1 Year

Every 1000 Service Hours

Every 2000 Service Hours

Every 3000 Service Hours

Every 4000 Service Hours

Every 6000 Service Hours or 3 Years

Every 12 000 Service Hours or 6 Years

i03632383

Aftercooler Core - Clean/Test
(Air-To-Air Aftercooler)

1. Remove the core. Refer to the OEM information for the correct procedure.
2. Turn the aftercooler core upside-down in order to remove debris.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

3. Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction of the fan's air flow. Hold the nozzle approximately 6 mm (.25 inch) away from the fins. Slowly move the air nozzle in a direction that is parallel with the tubes. This will remove debris that is between the tubes.
4. Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

NOTICE
Do not use a high concentration of caustic cleaner to clean the core. A high concentration of caustic cleaner can attack the internal metals of the core and cause leakage. Only use the recommended concentration of cleaner.

5. Back flush the core with a suitable cleaner.
6. Steam clean the core in order to remove any residue. Flush the fins of the aftercooler core. Remove any other trapped debris.
7. Wash the core with hot, soapy water. Rinse the core thoroughly with clean water.
8. Dry the core with compressed air. Direct the air in the reverse direction of the normal flow.
9. Inspect the core in order to ensure cleanliness. Pressure test the core. If necessary, repair the core.
10. Install the core. Refer to the OEM information for the correct procedure.
11. After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

i03632416

Aftercooler Core - Inspect

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the aftercooler for these items: damaged fins, corrosion, dirt, grease, insects, leaves, oil and other debris. Clean the aftercooler, if necessary.

For air-to-air aftercoolers, use the same methods that are used for cleaning radiators.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a “comb”.

Note: If parts of the aftercooler system are repaired or replaced, a leak test is highly recommended.

Inspect these items for good condition: Welds, mounting brackets, air lines, connections, clamps and seals. Make repairs, if necessary.

i02322311

Alternator - Inspect

Perkins recommends a scheduled inspection of the alternator. Inspect the alternator for loose connections and correct battery charging. Check the ammeter (if equipped) during engine operation in order to ensure correct battery performance and/or correct performance of the electrical system. Make repairs, as required.

Check the alternator and the battery charger for correct operation. If the batteries are correctly charged, the ammeter reading should be very near zero. All batteries should be kept charged. The batteries should be kept warm because temperature affects the cranking power. If the battery is too cold, the battery will not crank the engine. When the engine is not run for long periods of time or if the engine is run for short periods, the batteries may not fully charge. A battery with a low charge will freeze more easily than a battery with a full charge.

i02665597

Alternator and Fan Belts - Inspect/Adjust

Inspection

To maximize the engine performance, inspect the belts for wear and for cracking. Replace belts that are worn or damaged.

For applications that require multiple drive belts, replace the belts in matched sets. Replacing only one belt of a matched set will cause the new belt to carry more load because the older belt is stretched. The additional load on the new belt could cause the new belt to break.

If the belts are too loose, vibration causes unnecessary wear on the belts and pulleys. Loose belts may slip enough to cause overheating.

To accurately check the belt tension, a suitable gauge should be used.

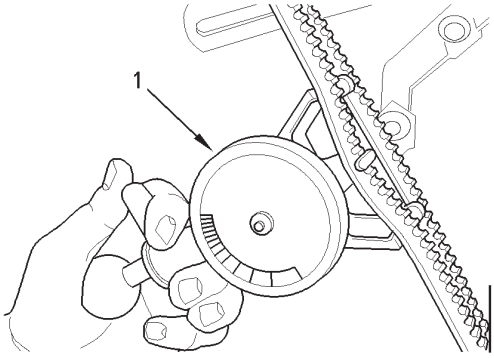

Illustration 33 g01003936

Typical example

(1) Burroughs Gauge

Install the gauge (1) at the center of the belt between the alternator and the crankshaft pulley and check the belt tension. The correct tension for a new belt is 400 N (90 lb) to 489 N (110 lb). The correct tension for a used belt that has been in operation for 30 minutes or more at the rated speed is 267 N (60 lb) to 356 N (80 lb).

If twin belts are installed, check and adjust the tension on both belts.

Adjustment

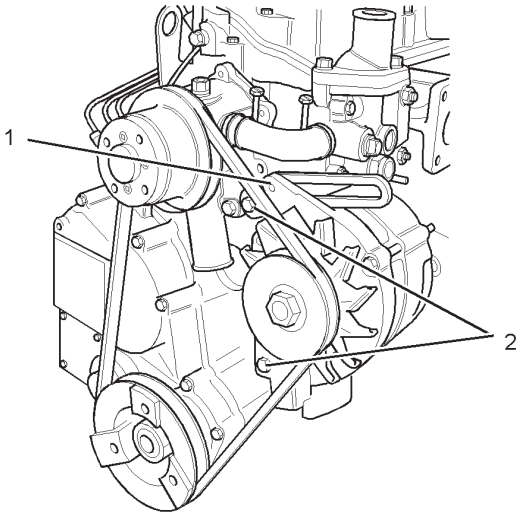

Illustration 34 g01091158

Typical example

(1) Adjusting bolt
(2) Mounting bolts

1. Loosen mounting bolts (2) and adjusting bolt (1).

2. Move the alternator in order to increase or decrease the belt tension.

3. Tighten adjusting bolt (1). Tighten mounting bolts (2). Refer to the Specifications Manual for the correct torque settings.

i02166560

Alternator and Fan Belts - Replace

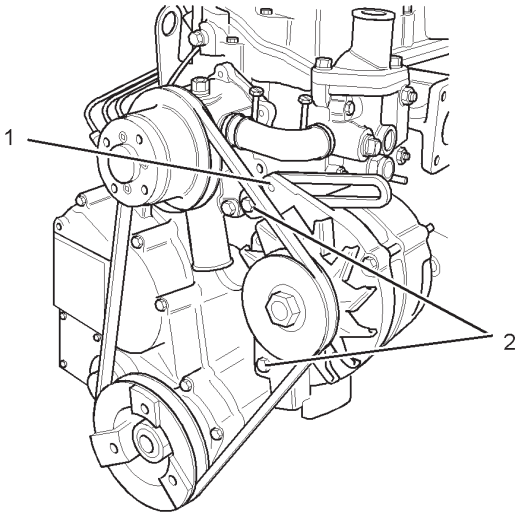

Illustration 35 g01091158

Typical example

(1) Adjusting bolt
(2) Mounting bolts

For applications that require multiple drive belts, replace the belts in matched sets. Replacing only one belt of a matched set will cause the new belt to carry more load because the older belt is stretched. The additional load on the new belt could cause the new belt to break.

Note: When new belts are installed, check the belt tension again after 20 hours of engine operation.

Refer to the Disassembly and Assembly Manual for the installation procedure and the removal procedure for the belt.

i02322315

Battery - Replace

⚠ WARNING

Batteries give off combustible gases which can explode. A spark can cause the combustible gases to ignite. This can result in severe personal injury or death.

Ensure proper ventilation for batteries that are in an enclosure. Follow the proper procedures in order to help prevent electrical arcs and/or sparks near batteries. Do not smoke when batteries are serviced.

⚠ WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Switch the engine to the OFF position. Remove all electrical loads.

2. Turn off any battery chargers. Disconnect any battery chargers.

3. The NEGATIVE “-” cable connects the NEGATIVE “-” battery terminal to the NEGATIVE “-” terminal on the starting motor. Disconnect the cable from the NEGATIVE “-” battery terminal.

4. The POSITIVE “+” cable connects the POSITIVE “+” battery terminal to the POSITIVE “+” terminal on the starting motor. Disconnect the cable from the POSITIVE “+” battery terminal.

Note: Always recycle a battery. Never discard a battery. Dispose of used batteries to an appropriate recycling facility.

5. Remove the used battery.

6. Install the new battery.

Note: Before the cables are connected, ensure that the engine start switch is OFF.

7. Connect the cable from the starting motor to the POSITIVE “+” battery terminal.

8. Connect the NEGATIVE “-” cable to the NEGATIVE “-” battery terminal.

i02747977

Battery Electrolyte Level - Check

When the engine is not run for long periods of time or when the engine is run for short periods, the batteries may not fully recharge. Ensure a full charge in order to help prevent the battery from freezing. If batteries are correctly charged, the ammeter reading should be very near zero, when the engine is in operation.

⚠ WARNING

All lead-acid batteries contain sulfuric acid which can burn the skin and clothing. Always wear a face shield and protective clothing when working on or near batteries.

1. Remove the filler caps. Maintain the electrolyte level to the “FULL” mark on the battery.

   If the addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

2. Check the condition of the electrolyte with a suitable battery tester.
3. Install the caps.
4. Keep the batteries clean.

   Clean the battery case with one of the following cleaning solutions:

   - Use a solution of 0.1 kg (0.2 lb) baking soda and 1 L (1 qt) of clean water.
   - Use a solution of ammonium hydroxide.

   Thoroughly rinse the battery case with clean water.

i02323088

Battery or Battery Cable - Disconnect

⚠ WARNING

The battery cables or the batteries should not be removed with the battery cover in place. The battery cover should be removed before any servicing is attempted.

Removing the battery cables or the batteries with the cover in place may cause a battery explosion resulting in personal injury.

1. Turn the start switch to the OFF position. Turn the ignition switch (if equipped) to the OFF position and remove the key and all electrical loads.
2. Disconnect the negative battery terminal. Ensure that the cable cannot contact the terminal. When four 12 volt batteries are involved, two negative connection must be disconnected.
3. Remove the positive connection.
4. Clean all disconnected connection and battery terminals.
5. Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright or shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit correctly. Coat the clamps and the terminals with a suitable silicone lubricant or petroleum jelly.
6. Tape the cable connections in order to help prevent accidental starting.
7. Proceed with necessary system repairs.
8. In order to connect the battery, connect the positive connection before the negative connector.

i02595666

Cooling System Coolant (Commercial Heavy-Duty) - Change

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to Local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator and the hoses, if necessary.

Drain

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

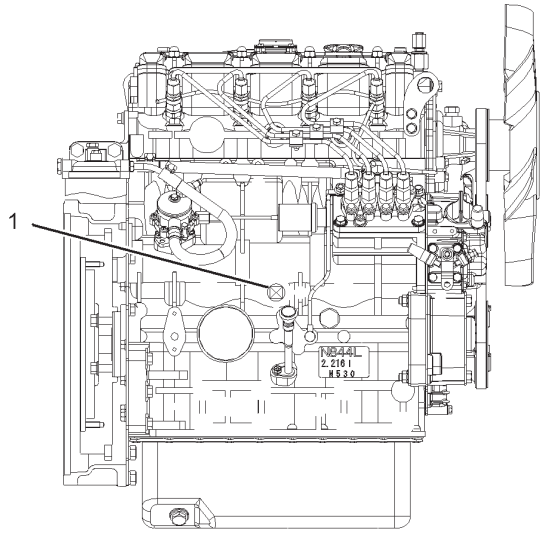

Illustration 36 g01301065
Typical example

2. Open the drain cock or remove the drain plug (1) on the engine. Open the drain cock or remove the drain plug on the radiator.

Allow the coolant to drain.

NOTICE
Dispose of used engine coolant or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Perkins to reclaim the coolant.

For information regarding the disposal and the recycling of used coolant, consult your Perkins dealer or your Perkins distributor.

Flush

1. Flush the cooling system with clean water in order to remove any debris.

2. Close the drain cock or install the drain plug in the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

3. Fill the cooling system with clean water. Install the cooling system filler cap.
4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).
5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain cock or remove the drain plug on the engine. Open the drain cock or remove the drain plug on the radiator. Allow the water to drain. Flush the cooling system with clean water.

Fill

1. Close the drain cock or install the drain plug on the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

2. Fill the cooling system with Commercial Heavy-Duty Coolant. Add Supplemental Coolant Additive to the coolant. For the correct amount, refer to the Operation and Maintenance Manual, “Fluid Recommendations” topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.
3. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Stop the engine.
4. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level in the expansion bottle (if equipped) at the correct level.
5. Clean the cooling system filler cap. Inspect the gasket that is on the cooling system filler cap. If the gasket that is on the cooling system filler cap is damaged, discard the old cooling system filler cap and install a new cooling system filler cap. If the gasket that is on the cooling system filler cap is not damaged, use a suitable pressurizing pump in order to pressure test the cooling system filler cap. The correct pressure for the cooling system filler cap is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not retain the correct pressure, install a new cooling system filler cap.
6. Start the engine. Inspect the cooling system for leaks and for correct operating temperature.

i02595733

Cooling System Coolant (ELC) - Change

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to Local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Clean the cooling system and flush the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- The oil has entered the cooling system and the coolant is contaminated.
- The fuel has entered the cooling system and the coolant is contaminated.

Note: When the cooling system is cleaned, only clean water is needed when the ELC is drained and replaced.

Note: Inspect the water pump and the water temperature regulator after the cooling system has been drained. This is a good opportunity to replace the water pump, the water temperature regulator and the hoses, if necessary.

Drain

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

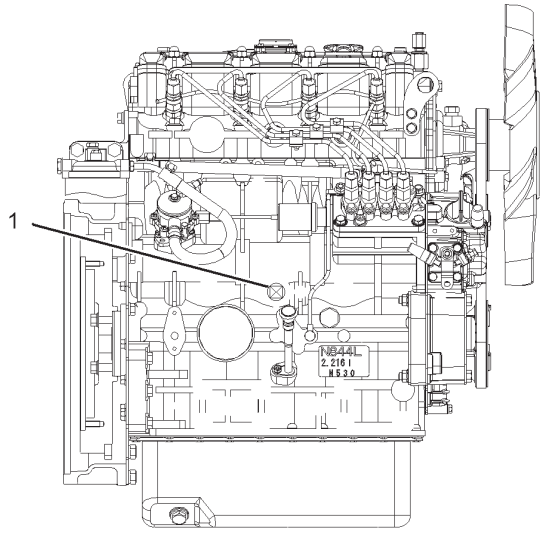

Illustration 37 g01301065

Typical example

2. Open the drain cock or remove the drain plug (1) on the engine. Open the drain cock or remove the drain plug on the radiator.

Allow the coolant to drain.

NOTICE
Dispose of used engine coolant or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Perkins to reclaim the coolant.

For information regarding the disposal and the recycling of used coolant, consult your Perkins dealer or your Perkins distributor.

Flush

1. Flush the cooling system with clean water in order to remove any debris.

2. Close the drain cock or install the drain plug in the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

3. Fill the cooling system with clean water. Install the cooling system filler cap.

4. Start and run the engine at low idle until the temperature reaches 49 to 66 °C (120 to 150 °F).

5. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the drain cock or remove the drain plug on the engine. Open the drain cock or remove the drain plug on the radiator. Allow the water to drain. Flush the cooling system with clean water.

Fill

1. Close the drain cock or install the drain plug on the engine. Close the drain cock or install the drain plug on the radiator.

NOTICE
Do not fill the cooling system faster than 5 L (1.3 US gal) per minute to avoid air locks.

Cooling system air locks may result in engine damage.

2. Fill the cooling system with Extended Life Coolant (ELC). Refer to the Operation and Maintenance Manual, “Fluid Recommendations” topic (Maintenance Section) for more information on cooling system specifications. Do not install the cooling system filler cap.

3. Start and run the engine at low idle. Increase the engine rpm to high idle. Run the engine at high idle for one minute in order to purge the air from the cavities of the engine block. Stop the engine.

4. Check the coolant level. Maintain the coolant level within 13 mm (0.5 inch) below the bottom of the pipe for filling. Maintain the coolant level in the expansion bottle (if equipped) at the correct level.
5. Clean the cooling system filler cap. Inspect the gasket that is on the cooling system filler cap. If the gasket that is on the cooling system filler cap is damaged, discard the old cooling system filler cap and install a new cooling system filler cap. If the gasket that is on the cooling system filler cap is not damaged, use a suitable pressurizing pump in order to pressure test the cooling system filler cap. The correct pressure for the cooling system filler cap is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not retain the correct pressure, install a new cooling system filler cap.
6. Start the engine. Inspect the cooling system for leaks and for correct operating temperature.

i04408743

Cooling System Coolant Level - Check

Engines With a Coolant Recovery Tank

Note: The cooling system may not have been provided by Perkins. The procedure that follows is for typical cooling systems. Refer to the OEM information for the correct procedures.

Check the coolant level when the engine is stopped and cool.

NOTICE
When any servicing or repair of the engine cooling system is performed, the procedure must be performed with the engine on level ground. This will allow you to accurately check the coolant level. This will also help in avoiding the risk of introducing an air lock into the coolant system.

1. Observe the coolant level in the coolant recovery tank. Maintain the coolant level to “COLD FULL” mark on the coolant recovery tank.

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

2. Loosen filler cap slowly in order to relieve any pressure. Remove the filler cap.
3. Pour the correct coolant mixture into the tank. Refer to the Operation and Maintenance Manual, “Refill Capacities and Recommendations” for information on the correct mixture and type of coolant. Refer to the Operation and Maintenance Manual, “Refill Capacities and Recommendations” for the cooling system capacity. Do not fill the coolant recovery tank above “COLD FULL” mark.

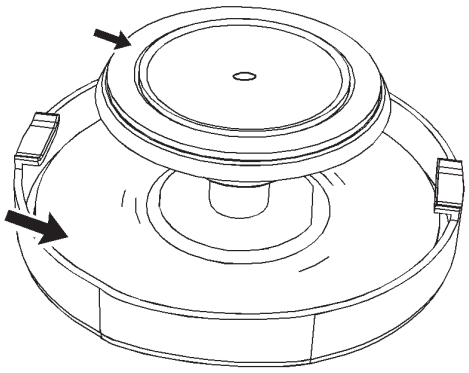

Illustration 38 g02590196
Filler cap

4. Clean filler cap and the receptacle. Reinstall the filler cap and inspect the cooling system for leaks.

Note: The coolant will expand as the coolant heats up during normal engine operation. The additional volume will be forced into the coolant recovery tank during engine operation. When the engine is stopped and cool, the coolant will return to the engine.

Engines Without a Coolant Recovery Tank

Check the coolant level when the engine is stopped and cool.

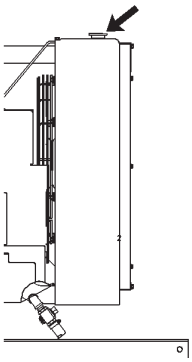

Illustration 39 g00285520
Cooling system filler cap

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly in order to relieve pressure.
2. Maintain the coolant level at the maximum mark that is correct for your application. If the engine is equipped with a sight glass, maintain the coolant level to the correct level in the sight glass.
3. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.
4. Inspect the cooling system for leaks.

i03644948

Cooling System Supplemental Coolant Additive (SCA) - Test/Add

⚠ WARNING

Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and the eyes. Do not drink cooling system coolant additive.

Test for SCA Concentration

Heavy-Duty Coolant/Antifreeze and SCA

NOTICE
Do not exceed the recommended six percent supplemental coolant additive concentration.

Use a Coolant Conditioner Test Kit in order to check the concentration of the SCA.

Add the SCA, If Necessary

NOTICE
Do not exceed the recommended amount of supplemental coolant additive concentration. Excessive supplemental coolant additive concentration can form deposits on the higher temperature surfaces of the cooling system, reducing the engine's heat transfer characteristics. Reduced heat transfer could cause cracking of the cylinder head and other high temperature components. Excessive supplemental coolant additive concentration could also result in radiator tube blockage, overheating, and/or accelerated water pump seal wear. Never use both liquid supplemental coolant additive and the spin-on element (if equipped) at the same time. The use of those additives together could result in supplemental coolant additive concentration exceeding the recommended maximum.

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

NOTICE
When any servicing or repair of the engine cooling system is performed the procedure must be performed with the engine on level ground. This will allow you to accurately check the coolant level. This will also help in avoiding the risk of introducing an air lock into the coolant system.

1. Slowly loosen the cooling system filler cap in order to relieve the pressure. Remove the cooling system filler cap.

Note: Always discard drained fluids according to local regulations.

2. If necessary, drain some coolant from the cooling system into a suitable container in order to allow space for the extra SCA.
3. Add the correct amount of SCA. Refer to the Operation and Maintenance Manual, “Refill Capacities and Recommendations” for more information on SCA requirements.
4. Clean the cooling system filler cap and inspect the gasket. If the gasket is damaged, discard the old filler cap and install a new filler cap. If the gasket is not damaged, use a suitable pressurizing pump in order to pressure test the filler cap. The correct pressure is stamped on the face of the filler cap. If the filler cap does not retain the correct pressure, install a new filler cap.

i03632420

Cooling System Water Temperature Regulator - Replace

Replace the water temperature regulator before the water temperature regulator fails. This is a recommended preventive maintenance practice. Replacing the water temperature regulator reduces the chances for unscheduled downtime.

A water temperature regulator that fails in a partially opened position can cause overheating or overcooling of the engine.

A water temperature regulator that fails in the closed position can cause excessive overheating. Excessive overheating could result in cracking of the cylinder head or piston seizure problems.

A water temperature regulator that fails in the open position will cause the engine operating temperature to be too low during partial load operation. Low engine operating temperatures during partial loads could cause an excessive carbon buildup inside the cylinders. This excessive carbon buildup could result in an accelerated wear of the piston rings and wear of the cylinder liner.

NOTICE
Failure to replace your water temperature regulator on a regularly scheduled basis could cause severe engine damage.

Perkins engines incorporate a shunt design cooling system and require operating the engine with a water temperature regulator installed.

If the water temperature regulator is installed incorrectly, the engine may overheat, causing cylinder head damage. Ensure that the new water temperature regulator is installed in the original position. Ensure that the water temperature regulator vent hole is open.

Do not use liquid gasket material on the gasket or cylinder head surface.

Refer to the Disassembly and Assembly Manual, “Water Temperature Regulator - Remove and Install” for the replacement procedure of the water temperature regulator, or consult your Perkins dealer or your Perkins distributor.

Note: If only the water temperature regulators are replaced, drain the coolant from the cooling system to a level that is below the water temperature regulator housing.

i02151646

Driven Equipment - Check

Refer to the OEM specifications for more information on the following maintenance recommendations for the driven equipment:

- Inspection
- Adjustment
- Lubrication
- Other maintenance recommendations

Perform any maintenance for the driven equipment which is recommended by the OEM.

i01936072

Engine - Clean

⚠ WARNING

Personal injury or death can result from high voltage.

Moisture can create paths of electrical conductivity.

Make sure that the electrical system is OFF. Lock out the starting controls and tag the controls "DO NOT OPERATE" .

NOTICE
Accumulated grease and oil on an engine is a fire hazard. Keep the engine clean. Remove debris and fluid spills whenever a significant quantity accumulates on the engine.

Periodic cleaning of the engine is recommended. Steam cleaning the engine will remove accumulated oil and grease. A clean engine provides the following benefits:

- Easy detection of fluid leaks
- Maximum heat transfer characteristics
- Ease of maintenance

Note: Caution must be used in order to prevent electrical components from being damaged by excessive water when the engine is cleaned. Pressure washers and steam cleaners should not be directed at any electrical connectors or the junction of cables into the rear of the connectors. Avoid electrical components such as the alternator, and the starter. Protect the fuel injection pump from fluids in order to wash the engine.

i02736653

Engine Air Cleaner Element (Dual Element) - Clean/Replace

NOTICE
Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent airborne debris from entering the air inlet.

NOTICE
Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

Servicing the Air Cleaner Elements

If the air cleaner element becomes plugged, the air can split the material of the air cleaner element. Unfiltered air will drastically accelerate internal engine wear. Your Perkins dealer has the proper air cleaner elements for your application. Consult your Perkins dealer for the correct air cleaner element.

- Check the precleaner (if equipped) daily for accumulation of dirt and debris. Remove any dirt and debris, as needed.
- Operating conditions (dust, dirt and debris) may require more frequent service of the air cleaner element.
- The air cleaner element may be cleaned up to six times if the element is properly cleaned and inspected.
- The air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Replace the dirty paper air cleaner elements with clean air cleaner elements. Before installation, the air cleaner elements should be thoroughly checked for tears and/or holes in the filter material. Inspect the gasket or the seal of the air cleaner element for damage. Maintain a supply of suitable air cleaner elements for replacement purposes.

Dual Element Air Cleaners

The dual element air cleaner contains a primary air cleaner element and a secondary air cleaner element. The primary air cleaner element can be used up to six times if the element is properly cleaned and inspected. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

The secondary air cleaner element is not serviceable or washable. The secondary air cleaner element should be removed and discarded for every three cleanings of the primary air cleaner element. When the engine is operating in environments that are dusty or dirty, air cleaner elements may require more frequent replacement.

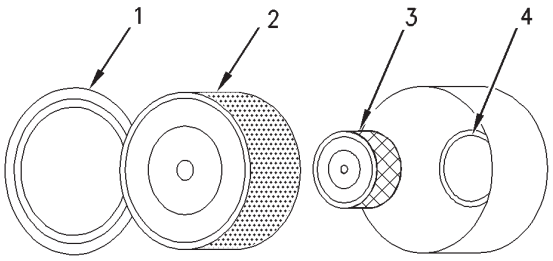

Illustration 40 g00736431

(1) Cover
(2) Primary air cleaner element
(3) Secondary air cleaner element
(4) Turbocharger air inlet

1. Remove the cover. Remove the primary air cleaner element.

2. The secondary air cleaner element should be removed and discarded for every three cleanings of the primary air cleaner element.

Note: Refer to “Cleaning the Primary Air Cleaner Elements”.

3. Cover the turbocharger air inlet with tape in order to keep dirt out.

4. Clean the inside of the air cleaner cover and body with a clean, dry cloth.

5. Remove the tape for the turbocharger air inlet. Install the secondary air cleaner element. Install a primary air cleaner element that is new or cleaned.

6. Install the air cleaner cover.

7. Reset the air cleaner service indicator.

Cleaning the Primary Air Cleaner Elements

NOTICE
Perkins recommends certified air filter cleaning services that are available at Perkins dealers. The Perkins cleaning process uses proven procedures to assure consistent quality and sufficient filter life.

Observe the following guidelines if you attempt to clean the filter element:

Do not tap or strike the filter element in order to remove dust.

Do not wash the filter element.

Use low pressure compressed air in order to remove the dust from the filter element. Air pressure must not exceed 207 kPa (30 psi). Direct the air flow up the pleats and down the pleats from the inside of the filter element. Take extreme care in order to avoid damage to the pleats.

Do not use air filters with damaged pleats, gaskets, or seals. Dirt entering the engine will cause damage to engine components.

The primary air cleaner element can be used up to six times if the element is properly cleaned and inspected. When the primary air cleaner element is cleaned, check for rips or tears in the filter material. The primary air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Use clean primary air cleaner elements while dirty elements are being cleaned.

NOTICE
Do not clean the air cleaner elements by bumping or tapping. This could damage the seals. Do not use elements with damaged pleats, gaskets or seals. Damaged elements will allow dirt to pass through. Engine damage could result.

Visually inspect the primary air cleaner elements before cleaning. Inspect the air cleaner elements for damage to the seal, the gaskets, and the outer cover. Discard any damaged air cleaner elements.

There are two common methods that are used to clean primary air cleaner elements:

- Pressurized air
- Vacuum cleaning

Pressurized Air

Pressurized air can be used to clean primary air cleaner elements that have not been cleaned more than two times. Pressurized air will not remove deposits of carbon and oil. Use filtered, dry air with a maximum pressure of 207 kPa (30 psi).

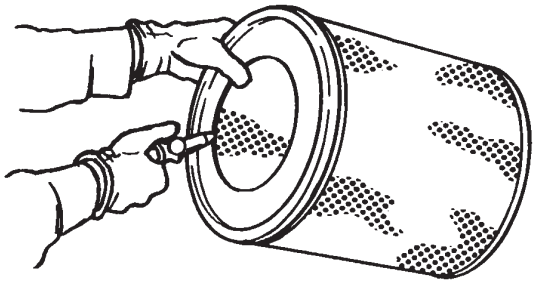

Illustration 41 g00281692

Note: When the primary air cleaner elements are cleaned, always begin with the clean side (inside) in order to force dirt particles toward the dirty side (outside).

Aim the hose so that the air flows inside the element along the length of the filter in order to help prevent damage to the paper pleats. Do not aim the stream of air directly at the primary air cleaner element. Dirt could be forced further into the pleats.

Note: Refer to “Inspecting the Primary Air Cleaner Elements”.

Vacuum Cleaning

Vacuum cleaning is a good method for cleaning primary air cleaner elements which require daily cleaning because of a dry, dusty environment. Cleaning with pressurized air is recommended prior to vacuum cleaning. Vacuum cleaning will not remove deposits of carbon and oil.

Note: Refer to “Inspecting the Primary Air Cleaner Elements”.

Inspecting the Primary Air Cleaner Elements

Illustration 42 g00281693

Inspect the clean, dry primary air cleaner element. Use a 60 watt blue light in a dark room or in a similar facility. Place the blue light in the primary air cleaner element. Rotate the primary air cleaner element. Inspect the primary air cleaner element for tears and/or holes. Inspect the primary air cleaner element for light that may show through the filter material. If it is necessary in order to confirm the result, compare the primary air cleaner element to a new primary air cleaner element that has the same part number.

Do not use a primary air cleaner element that has any tears and/or holes in the filter material. Do not use a primary air cleaner element with damaged pleats, gaskets or seals. Discard damaged primary air cleaner elements.

Storing Primary Air Cleaner Elements

If a primary air cleaner element that passes inspection will not be used, the primary air cleaner element can be stored for future use.

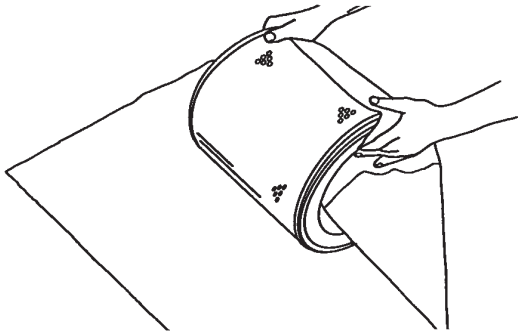

Illustration 43 g00281694

Do not use paint, a waterproof cover, or plastic as a protective covering for storage. An air flow restriction may result. To protect against dirt and damage, wrap the primary air cleaner elements in Volatile Corrosion Inhibited (VCI) paper.

Place the primary air cleaner element into a box for storage. For identification, mark the outside of the box and mark the primary air cleaner element. Include the following information:

- Date of cleaning
- Number of cleanings

Store the box in a dry location.

i02152042

Engine Air Cleaner Element (Single Element) - Inspect/ Replace

Refer to Operation and Maintenance Manual, “Engine Air Cleaner Service Indicator-Inspect”.

NOTICE
Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent airborne debris from entering the air inlet.

NOTICE
Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

A wide variety of air cleaners may be installed for use with this engine. Consult the OEM information for the correct procedure to replace the air cleaner.

i02335405

Engine Air Cleaner Service Indicator - Inspect

Some engines may be equipped with a different service indicator.

Some engines are equipped with a differential gauge for inlet air pressure. The differential gauge for inlet air pressure displays the difference in the pressure that is measured before the air cleaner element and the pressure that is measured after the air cleaner element. As the air cleaner element becomes dirty, the pressure differential rises. If your engine is equipped with a different type of service indicator, follow the OEM recommendations in order to service the air cleaner service indicator.

The service indicator may be mounted on the air cleaner element or in a remote location.

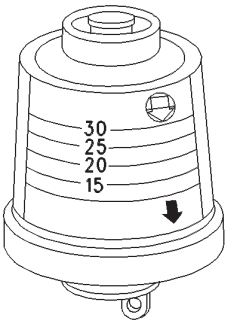

Illustration 44 g00103777
Typical service indicator

Observe the service indicator. The air cleaner element should be cleaned or the air cleaner element should be replaced when one of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.

Test the Service Indicator

Service indicators are important instruments.

- Check for ease of resetting. The service indicator should reset in less than three pushes.
- Check the movement of the yellow core when the engine is accelerated to the engine rated speed. The yellow core should latch at the greatest vacuum that is attained.

If the service indicator does not reset easily, or if the yellow core does not latch at the greatest vacuum, the service indicator should be replaced. If the new service indicator will not reset, the hole for the service indicator may be restricted.

The service indicator may need to be replaced frequently in environments that are severely dusty.

i02927289

Engine Air Precleaner - Check/Clean

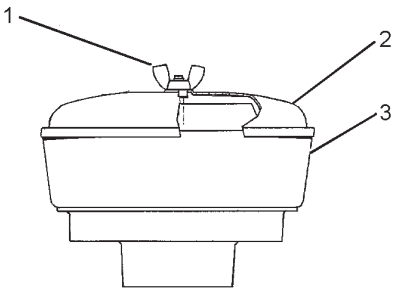

Illustration 45 g01453058

Typical engine air precleaner

(1) Wing nut
(2) Cover
(3) Body

Remove wing nut (1) and cover (2). Check for an accumulation of dirt and debris in body (3). Clean the body, if necessary.

After cleaning the precleaner, install cover (2) and wing nut (1).

Note: When the engine is operated in dusty applications, more frequent cleaning is required.

i02657627

Engine Crankcase Breather - Replace

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

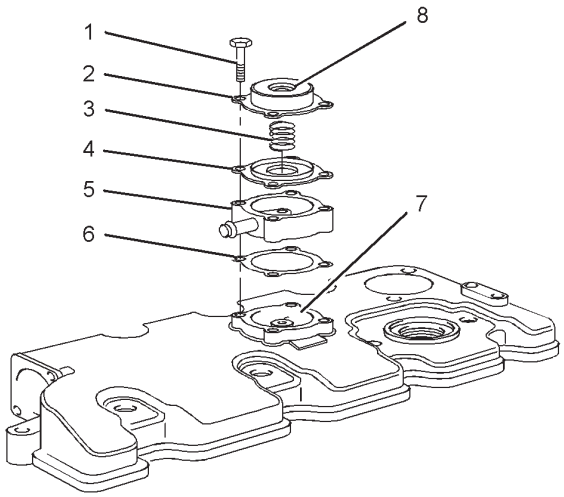

Illustration 46 g01335247

Typical example

(1) Screws for the breather cover
(2) Breather cover
(3) Spring
(4) Diaphragm and plate
(5) Spacer for turbocharged engines only
(6) Joint for turbocharged engines only
(7) Cavity
(8) Vent hole

1. Loosen the screws (1) and remove the breather cover (2) from the valve mechanism cover.

2. Remove the spring (3). Remove the diaphragm and plate (4).

3. For turbocharged engines, remove the spacer (5) and the joint (6).

4. Clean the vent hole (8) and the cavity (7) in the valve mechanism cover.

NOTICE
Make sure that the components of the breather assembly are installed correctly. Engine damage may occur if the breather assembly is not working correctly.

5. For turbocharged engines, install a new joint (6) and the spacer (5).

6. Install a new diaphragm and plate (4) for the breather assembly into the cavity (7) of the valve mechanism cover or the spacer (5) for turbocharged engines.
7. Install a new spring (3).
8. Install the breather cover (2) and the four screws (1). Tighten the screws.

i02323089

Engine Mounts - Inspect

Note: The engine mounts may not have been supplied by Perkins. Refer to the OEM information for further information on the engine mounts and the correct bolt torque.

Inspect the engine mounts for deterioration and for correct bolt torque. Engine vibration can be caused by the following conditions:

- Incorrect mounting of the engine
- Deterioration of the engine mounts
- Loose engine mounts

Any engine mount that shows deterioration should be replaced. Refer to the OEM information for the recommended torques.

i02153660

Engine Oil Level - Check

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

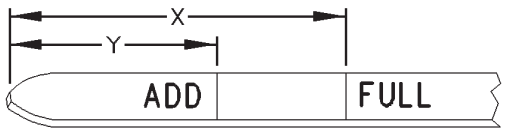

Illustration 47 g00110310

(Y) “ADD” mark. (X) “FULL” mark.

NOTICE
Perform this maintenance with the engine stopped.

1. Maintain the oil level between “ADD” mark (Y) and “FULL” mark (X) on oil level gauge (1). Do not fill the crankcase above “FULL” mark (X).

NOTICE
Operating your engine when the oil level is above the “FULL” mark could cause your crankshaft to dip into the oil. The air bubbles created from the crankshaft dipping into the oil reduces the oil's lubricating characteristics and could result in the loss of power.

2. Remove the oil filler cap and add oil, if necessary. Clean the oil filler cap. Install the oil filler cap.

i02610655

Engine Oil and Filter - Change

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Do not drain the oil when the engine is cold. As the oil cools, suspended waste particles settle on the bottom of the oil pan. The waste particles are not removed with the draining cold oil. Drain the crankcase with the engine stopped. Drain the crankcase with the oil warm. This draining method allows the waste particles that are suspended in the oil to be drained correctly.

Failure to follow this recommended procedure will cause the waste particles to be recirculated through the engine lubrication system with the new oil.

Drain the Engine Oil

After the engine has been run at the normal operating temperature, stop the engine. Use one of the following methods to drain the engine crankcase oil:

- If the engine is equipped with a drain valve, turn the drain valve knob counterclockwise in order to drain the oil. After the oil has drained, turn the drain valve knob clockwise in order to close the drain valve.
- If the engine is not equipped with a drain valve, remove the oil drain plug in order to allow the oil to drain. After the oil has drained, the oil drain plug should be cleaned and installed.

Replace the Oil Filter

NOTICE
Perkins oil filters are built to Perkins specifications. Use of an oil filter not recommended by Perkins could result in severe engine damage to the engine bearings, crankshaft, etc., as a result of the larger waste particles from unfiltered oil entering the engine lubricating system. Only use oil filters recommended by Perkins.

1. Remove the oil filter with a suitable tool.

Note: The following actions can be carried out as part of the preventive maintenance program.

2. Cut the oil filter open with a suitable tool. Break apart the pleats and inspect the oil filter for metal debris. An excessive amount of metal debris in the oil filter may indicate early wear or a pending failure.

Use a magnet to differentiate between the ferrous metals and the nonferrous metals that are found in the oil filter element. Ferrous metals may indicate wear on the steel and cast iron parts of the engine.

Nonferrous metals may indicate wear on the aluminum parts, brass parts or bronze parts of the engine. Parts that may be affected include the following items: main bearings, rod bearings, turbocharger bearings and cylinder heads.

Due to normal wear and friction, it is not uncommon to find small amounts of debris in the oil filter. Consult your Perkins dealer or your Perkins distributor in order to arrange for a further analysis if an excessive amount of debris is found in the oil filter.

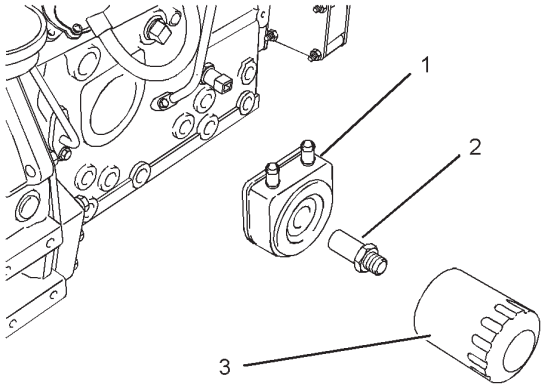

Illustration 48 g01334593

(1) Oil cooler
(2) Adapter
(3) Oil filter

Note: The oil cooler (1) and the adapter (2) are installed on engines that have a turbocharger.

3. Clean the sealing surface of the cylinder block or the oil cooler (1).

4. Apply clean engine oil to the new oil filter seal (3).

NOTICE
Do not fill the oil filters with oil before installing them. This oil would not be filtered and could be contaminated. Contaminated oil can cause accelerated wear to engine components.

5. Install the oil filter. Tighten the oil filter by hand. Do not overtighten the oil filter.

Fill the Engine Crankcase

1. Remove the oil filler cap. Refer to the Operation and Maintenance Manual for more information on lubricant specifications. Fill the crankcase with the correct amount of oil. Refer to the Operation and Maintenance Manual for more information on refill capacities.

NOTICE
If equipped with an auxiliary oil filter system or a remote oil filter system, follow the OEM or filter manufacturer's recommendations. Under filling or overfilling the crankcase with oil can cause engine damage.

NOTICE
To prevent crankshaft bearing damage, crank the engine with the fuel OFF. This will fill the oil filters before starting the engine. Do not crank the engine for more than 30 seconds.

2. Start the engine and run the engine at “LOW IDLE” for two minutes. Perform this procedure in order to ensure that the lubrication system has oil and that the oil filters are filled. Inspect the oil filter for oil leaks.
3. Stop the engine and allow the oil to drain back to the sump for a minimum of ten minutes.

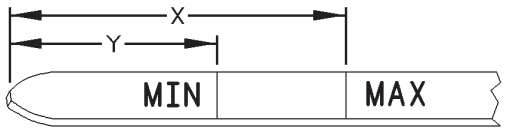

Illustration 49 g00986928
Typical example

4. Remove the oil level gauge in order to check the oil level. Maintain the oil level between the “MIN” and “MAX” marks on the oil level gauge.

i02676023

Engine Valve Lash - Inspect/Adjust

This maintenance is recommended by Perkins as part of a lubrication and preventive maintenance schedule in order to help provide maximum engine life. The maintenance for the valve lash is important in order to keep the engine compliant.

NOTICE
Only qualified service personel should perform this maintenance. Refer to the Service Manual or your authorized Perkins dealer or your Perkins distributor for the complete valve lash adjustment procedure.

Operation of Perkins engines with incorrect valve lash can reduce engine efficiency, and also reduce engine component life.

⚠ WARNING

Ensure that the engine can not be started while this maintenance is being performed. To help prevent possible injury, do not use the starting motor to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring/adjusting valve lash clearance.

Ensure that the engine is stopped before measuring the valve lash. The engine valve lash can be inspected and adjusted when the temperature of the engine is hot or cold.

Refer to Systems Operation, Testing and Adjusting, “Engine Valve Lash - Inspect/Adjust” for more information.

i02154268

Fuel Injector - Test/Change

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire.

⚠ WARNING

Make sure that you wear eye protection at all times during testing. When fuel injection nozzles are tested, test fluids travel through the orifices of the nozzle tip with high pressure. Under this amount of pressure, the test fluid can pierce the skin and cause serious injury to the operator. Always keep the tip of the fuel injection nozzle pointed away from the operator and into the fuel collector and extension.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

Regular maintenance of the fuel injectors is recommended by Perkins. The fuel injectors must be removed and tested by an authorized agent. The fuel injectors should not be cleaned as cleaning with incorrect tools can damage the nozzle. The fuel injectors should be renewed only if a fault with the fuel injectors occurs. Some of the problems that may indicate that new fuel injectors are needed are listed below:

- The engine will not start or the engine is difficult to start.

- Not enough power
- The engine misfires or the engine runs erratically.
- High fuel consumption
- Black exhaust smoke
- The engine knocks or there is vibration in the engine.
- Excessive engine temperature

For further information on the removal and the installation of the fuel injectors, refer to the Disassembly and Assembly manual.

For further information on the testing of fuel injectors, refer to the Testing and Adjusting manual.

Identification of a suspect Fuel Injector

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

NOTICE
If your skin comes into contact with high pressure fuel, obtain medical assistence immediately.

NOTICE
If a fuel injector is suspected of operating outside of normal parameters it should be removed by a qualified technician. The suspect fuel injector should be taken to an authorised agent for inspection.

Operate the engine at a fast idle speed in order to identify the faulty fuel injector. Individually loosen and tighten the union nut for the high pressure pipe to each fuel injector. Do not loosen the union nut more than half a turn. There will be little effect on the engine speed when the union nut to the faulty fuel injector is loosened.

Consult your authorized Perkins dealer or your Perkins distributor for further assistance.

i02596360

Fuel System - Prime

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Use the following procedure in order to prime the fuel system:

If air enters the fuel system, the air must be purged from the fuel system before the engine can be started. Air can enter the fuel system when the following events occur:

- The fuel tank is empty or the fuel tank has been partially drained.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system.
- The fuel filter is replaced.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Primary filter

Ensure that the air is removed from the primary filter before you prime the fuel filters. Refer to illustration 50 .

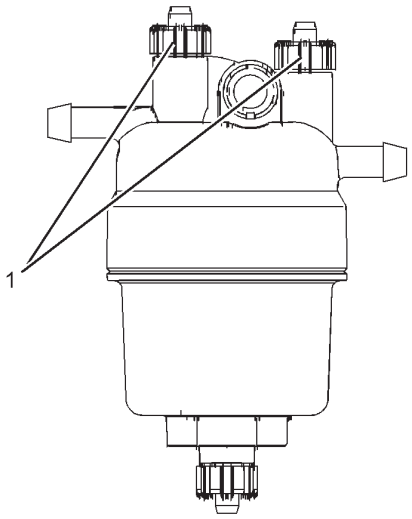

Illustration 50 g01316878

This filter may not be installed on the engine.

(1) Vent screws

Fuel filters

There are three types of fuel filter that may be installed on the engine.

- Element
- Canister
- Spin-on filter with fuel priming pump

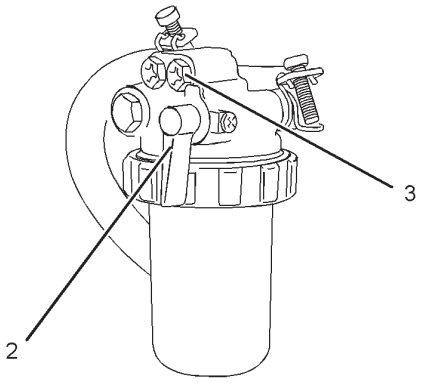

Illustration 51 g01327360

Element

(2) Fuel valve
(3) Vent screw

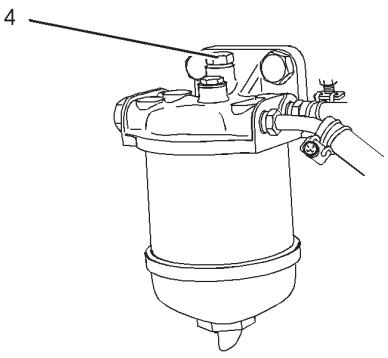

Illustration 52 g01327361

Canister

(4) Vent screw

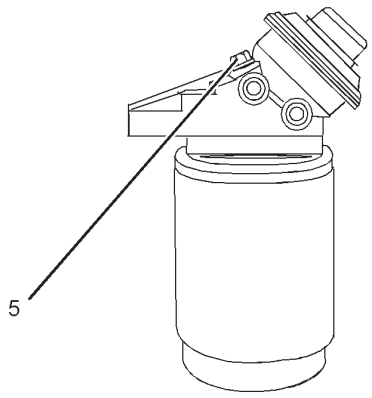

Illustration 53 g01327363

Spin-on filter with fuel priming pump

(5) Vent screw

Vent screw (3) is installed on the filter that has an element. Vent screw (4) is installed on the fuel filter that has a canister. Vent screw (5) is installed on the spin-on filter.

Priming the system

Ensure that the air is removed from the primary filter. Loosen vent screws (1). Refer to illustration 50 . Operate the priming pump. When fuel free from air flows from the vent screw tighten the vent screw.

Note: Some fuel system will use gravity in order to prime the primary fuel filter. If gravity is used ensure that the fuel tank is full and that all stop valves in the fuel line are open.

There is four different types of systems that can be installed on the engine in order to prime the fuel system. Refer to illustration 54 .

- Hand priming pump
- In-line hand priming pump
- Electrical priming pump
- Transfer pump that is operated by the starting motor

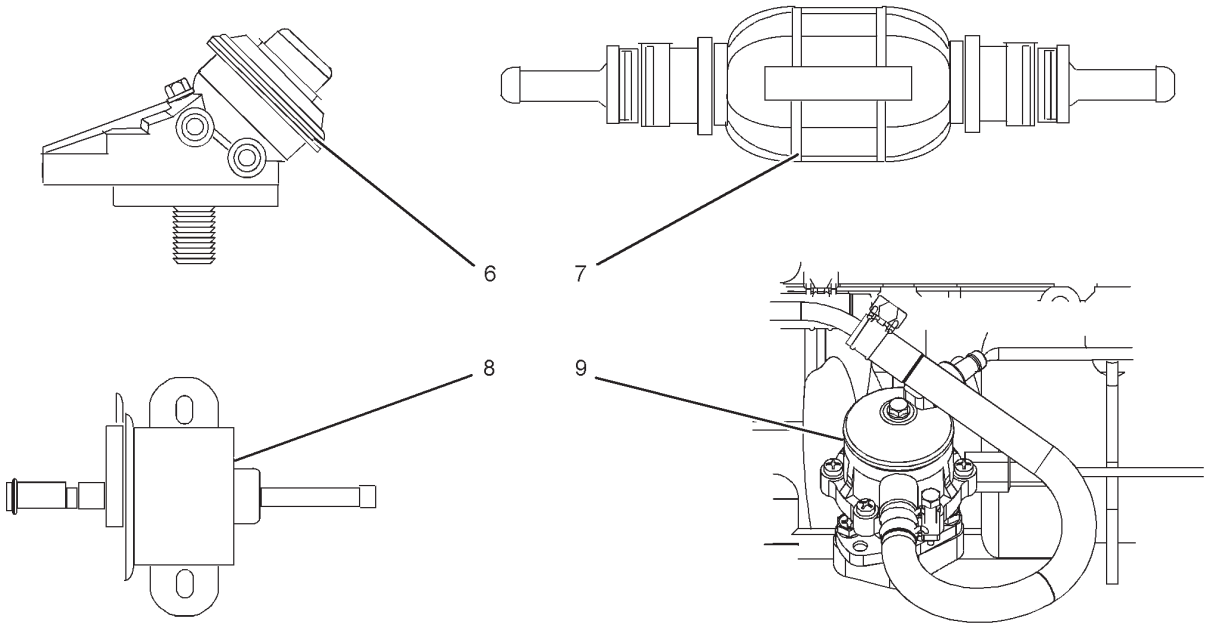

Illustration 54 g01301853

(6) Hand priming pump
(7) In-line priming pump
(8) Electrical priming pump
(9) Fuel transfer pump

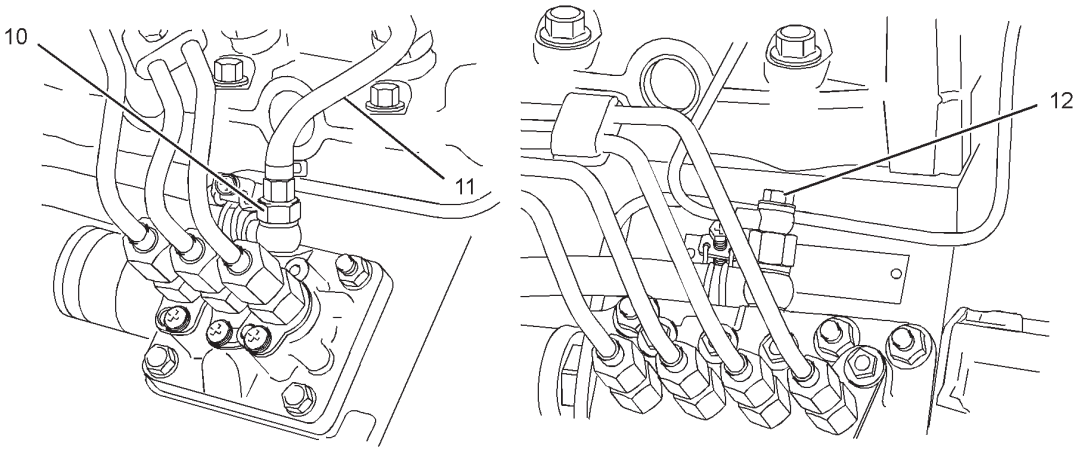

Illustration 55 g01304597

(10) Connector bolt
(11) Fuel return line
(12) Connector bolt

Hand Priming Pump 6

In order to identify the hand priming pump, refer to illustration 54 .

1. Ensure that fuel valve (2) for the fuel filter that has an element is in the ON position. Refer to illustration 51 .

2. Loosen vent screw (3 4 or 5) on the fuel filter.

3. Operate hand priming pump (6). When fuel free from air flows from the vent screw tighten the vent screw.

4. Loosen connection (10 or 12) at the fuel injection pump. Refer to illustration 55 .

Note: Fuel return line (11) may need to be removed in order to prime the fuel system.

5. Operate the hand priming pump. When fuel free from air flows from the connections tighten the connecting bolt.

6. The engine should now be able to start. Operate the starting motor in order to start the engine.

Note: Do not operate the starting motor for more than 15 seconds. If the engine does not start after 15 seconds, stop and wait for 30 seconds before trying again.

In-line Priming Pump 7

In order to identify the in-line priming pump, refer to illustration 54 .

1. Ensure that fuel valve (2) for the fuel filter that has an element is in the ON position. Refer to illustration 51 .

2. Loosen vent screw (3 4 or 5) on the fuel filter.

3. Operate in-line priming pump (7). When fuel free from air flows from the vent screw tighten the vent screw.

4. Loosen connection (10 or 12) at the fuel injection pump. Refer to illustration 55 .

Note: Fuel return line (11) may need to be removed in order to prime the fuel system.

5. Operate the in-line priming pump. When fuel free from air flows from the connections tighten the connecting bolt.

6. The engine should now be able to start. Operate the starting motor in order to start the engine.

Note: Do not operate the starting motor for more than 15 seconds. If the engine does not start after 15 seconds, stop and wait for 30 seconds before trying again.

Electrical Priming Pump 8

In order to identify the electrical priming pump, refer to illustration 54 .

1. Ensure that fuel valve (2) for the fuel filter that has an element is in the ON position. Refer to illustration 51 .

2. Loosen vent screw (3 4 or 5) on the fuel filter.

3. Operate electrical priming pump (8). When fuel free from air flows from the vent screw tighten the vent screw. Switch off the electrical priming pump.

4. Loosen connection (10 or 12) at the fuel injection pump. Refer to illustration 55 .

Note: Fuel return line (11) may need to be removed in order to prime the fuel system.

5. Operate the in-line priming pump. When fuel free from air flows from the connections tighten the connecting bolt.

6. The engine should now be able to start. Operate the starting motor in order to start the engine.

Note: Do not operate the starting motor for more than 15 seconds. If the engine does not start after 15 seconds, stop and wait for 30 seconds before trying again.

Fuel Transfer Pump 9

In order to identify the fuel transfer pump, refer to illustration 54 .

Note: In order to use the transfer pump, you must operate the starting motor. Do not operate the starting motor for more than 15 seconds. After 15 seconds, stop and wait for 30 seconds before operating the starting motor.

1. Ensure that fuel valve (2) for the fuel filter that has an element is in the ON position. Refer to illustration 51 .

2. Loosen vent screw (3 4 or 5) on the fuel filter.

3. Operate fuel transfer pump (9). When fuel free from air flows from the vent screw tighten the vent screw. Stop the fuel transfer pump.

4. Loosen connection (10 or 12) at the fuel injection pump. Refer to illustration 55 .

Note: Fuel return line (11) may need to be removed in order to prime the fuel system.

5. Operate the fuel transfer pump. When fuel free from air flows from the connections tighten the connecting bolt. Stop the transfer pump.

6. The engine should now be able to start. Operate the starting motor in order to start the engine.

Note: Do not operate the starting motor for more than 15 seconds. If the engine does not start after 15 seconds, stop and wait for 30 seconds before trying again.

i02608681

Fuel System Filter - Replace

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Fuel Filter with Canister

1. Close the fuel supply valve.

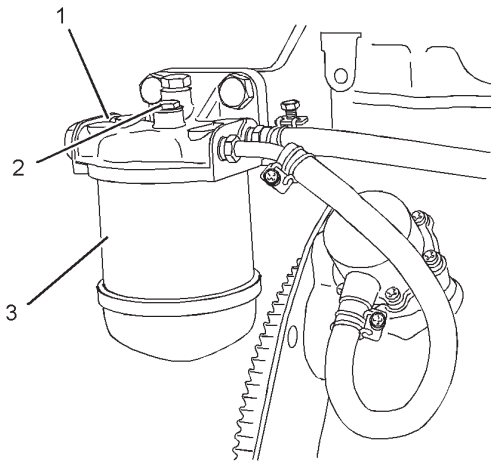

Illustration 56 g01307792
Typical example

2. Clean the outside of the fuel filter assembly (1).

3. Remove setscrew (2).

4. Remove the canister (3). Ensure that any fluid is drained into a suitable container.

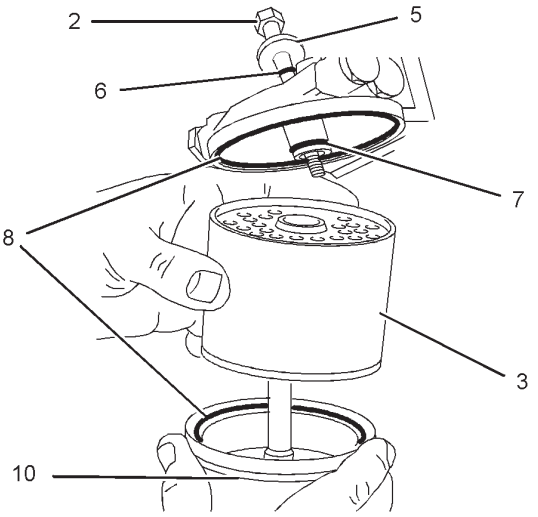

Illustration 57 g01334877
Typical example

5. Assemble the following items: seals (8), seal (7), canister (3) and bowl (10). Place washer (5) and seal (6) on setscrew (2).

6. Fasten the assembly to the fuel filter base with setscrew (2).

The fuel system will need to be primed after the new filter is installed. Refer to this Operation and Maintenance Manual, “Fuel System - Prime”.

Fuel Filter with Element

1. Close the fuel supply valve (1).

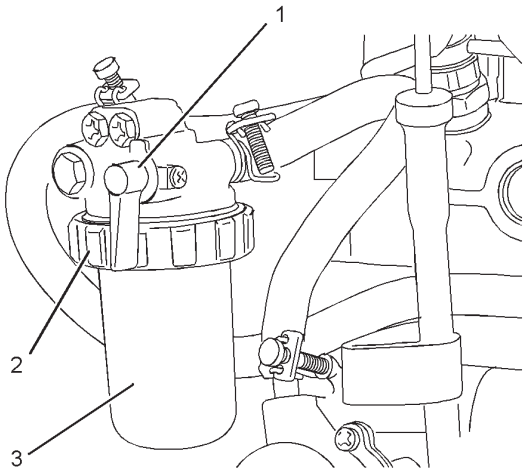

Illustration 58 g01334893
Typical example

2. Clean the outside of the fuel filter assembly.

3. Loosen the locking ring (2).

4. Remove the casing (3) for the filter and the element. Ensure that any fluid is drained into a suitable container.

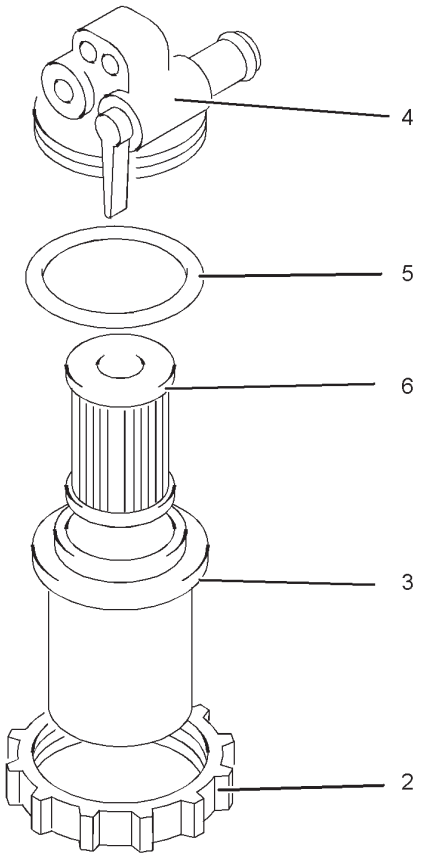

Illustration 59 g01334895
Typical example

Note: Do not fill the fuel filter with fuel. The fuel will not be filtered and the fuel could be contaminated. Contaminated fuel can damage your fuel system.

5. Assemble the following items: seal (5), filter element (6) and casing (3).

6. Install the assembled items to the filter base (4).

7. Install the locking ring (2) to the filter head. Rotate the locking ring in order to lock the assembly.

The fuel system will need to be primed after the new filter is installed. Refer to this Operation and Maintenance Manual, “Fuel System - Prime”.

Fuel Filter with Priming Pump

1. Close the fuel supply valve.

2. Clean the outside of the fuel filter assembly.

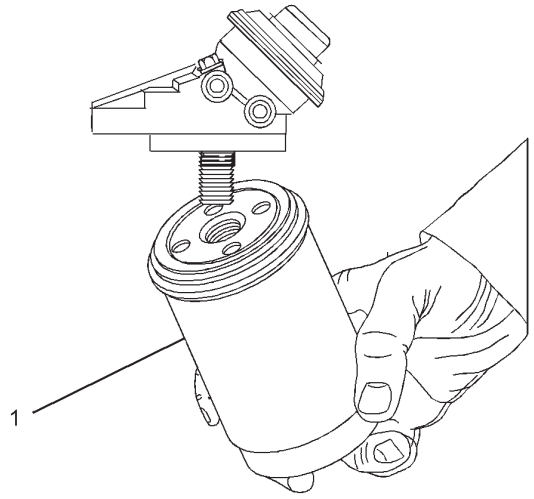

Illustration 60 g01306131
Typical example

3. By using a suitable tool, remove spin-on filter (1). Ensure that any fluid is drained into a suitable container.

Note: Do not fill the fuel filter with fuel. The fuel will not be filtered and the fuel could be contaminated. Contaminated fuel can damage your fuel system.

4. Install the new spin-on filter. Tighten the spin-on filter by hand.

The fuel system will need to be primed after the new filter is installed. Refer to this Operation and Maintenance Manual, “Fuel System - Prime”.

i02627223

Fuel System Primary Filter/ Water Separator - Drain

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE
The water separator is not a filter. The water separator separates water from the fuel. The engine should never be allowed to run with the water separator more than half full. Engine damage may result.

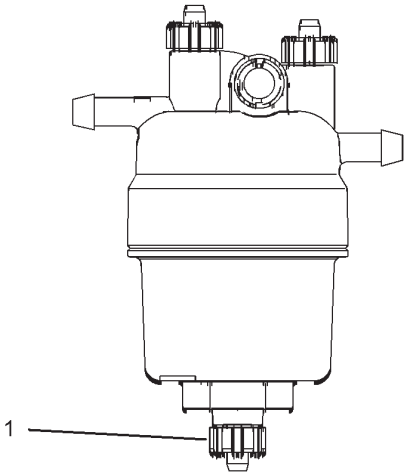

Illustration 61 g01316965
Typical example

1. Open drain (1). Catch the draining fluid in a suitable container. Dispose of the drained fluid correctly.

2. Close drain (1).

NOTICE
The water separator is under suction during normal engine operation. Ensure that the drain valve is tightened securely to help prevent air from entering the fuel system.

i02335436

Fuel Tank Water and Sediment - Drain

NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Fuel Tank

Fuel quality is critical to the performance and to the service life of the engine. Water in the fuel can cause excessive wear to the fuel system.

Water can be introduced into the fuel tank when the fuel tank is being filled.

Condensation occurs during the heating and cooling of fuel. The condensation occurs as the fuel passes through the fuel system and the fuel returns to the fuel tank. This causes water to accumulate in fuel tanks. Draining the fuel tank regularly and obtaining fuel from reliable sources can help to eliminate water in the fuel.

Drain the Water and the Sediment

Fuel tanks should contain some provision for draining water and draining sediment from the bottom of the fuel tanks.

Open the drain valve on the bottom of the fuel tank in order to drain the water and the sediment. Close the drain valve.

Check the fuel daily. Allow five minutes after the fuel tank has been filled before draining water and sediment from the fuel tank.

Fill the fuel tank after operating the engine in order to drive out moist air. This will help prevent condensation. Do not fill the tank to the top. The fuel expands as the fuel gets warm. The tank may overflow.

Some fuel tanks use supply pipes that allow water and sediment to settle below the end of the fuel supply pipe. Some fuel tanks use supply lines that take fuel directly from the bottom of the tank. If the engine is equipped with this system, regular maintenance of the fuel system filter is important.

Fuel Storage Tanks

Drain the water and the sediment from the fuel storage tank at the following intervals:

- Weekly
- Service intervals
- Refill of the tank

This will help prevent water or sediment from being pumped from the storage tank into the engine fuel tank.

If a bulk storage tank has been refilled or moved recently, allow adequate time for the sediment to settle before filling the engine fuel tank. Internal baffles in the bulk storage tank will also help trap sediment. Filtering fuel that is pumped from the storage tank helps to ensure the quality of the fuel. When possible, water separators should be used.

i02813964

Hoses and Clamps - Inspect/ Replace

Inspect all hoses for leaks that are caused by the following conditions:

- Cracking
- Softness
- Loose clamps

Replace hoses that are cracked or soft. Tighten any loose clamps.

NOTICE
Do not bend or strike high pressure lines. Do not install bent or damaged lines, tubes or hoses. Repair any loose or damaged fuel and oil lines, tubes and hoses. Leaks can cause fires. Inspect all lines, tubes and hoses carefully. Tighten all connections to the recommended torque. Do not clip any other item to the high pressure lines.

Check for the following conditions:

- End fittings that are damaged or leaking
- Outer covering that is chafed or cut
- Exposed wire that is used for reinforcement
- Outer covering that is ballooning locally
- Flexible part of the hose that is kinked or crushed
- Armoring that is embedded in the outer covering

A constant torque hose clamp can be used in place of any standard hose clamp. Ensure that the constant torque hose clamp is the same size as the standard clamp.

Due to extreme temperature changes, the hose will harden. Hardening of the hoses will cause hose clamps to loosen. This can result in leaks. A constant torque hose clamp will help to prevent loose hose clamps.

Each installation application can be different. The differences depend on the following factors:

- Type of hose
- Type of fitting material
- Anticipated expansion and contraction of the hose
- Anticipated expansion and contraction of the fittings

Replace the Hoses and the Clamps

Refer to the OEM information for further information on removing and replacing fuel hoses (if equipped).

The coolant system and the hoses for the coolant system are not usually supplied by Perkins. The following text describes a typical method of replacing coolant hoses. Refer to the OEM information for further information on the coolant system and the hoses for the coolant system.

⚠ WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine. Allow the engine to cool.
2. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

Note: Drain the coolant into a suitable, clean container. The coolant can be reused.

3. Drain the coolant from the cooling system to a level that is below the hose that is being replaced.
4. Remove the hose clamps.
5. Disconnect the old hose.
6. Replace the old hose with a new hose.
7. Install the hose clamps with a torque wrench.

Note: For the correct coolant, see this Operation and Maintenance Manual, “Fluid Recommendations”.

8. Refill the cooling system. Refer to the OEM information for further information on refilling the cooling system.
9. Clean the cooling system filler cap. Inspect the cooling system filler cap's seals. Replace the cooling system filler cap if the seals are damaged. Install the cooling system filler cap.
10. Start the engine. Inspect the cooling system for leaks.

i02335774

Radiator - Clean

The radiator is not usually supplied by Perkins. The following text describes a typical cleaning procedure for the radiator. Refer to the OEM information for further information on cleaning the radiator.

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the radiator for these items: Damaged fins, corrosion, dirt, grease, insects, leaves, oil and other debris. Clean the radiator, if necessary.

⚠ WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction to the fan's air flow. Hold the nozzle approximately 6 mm (0.25 inch) away from the radiator fins. Slowly move the air nozzle in a direction that is parallel with the radiator tube assembly. This will remove debris that is between the tubes.

Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

Use a degreaser and steam for removal of oil and grease. Clean both sides of the core. Wash the core with detergent and hot water. Thoroughly rinse the core with clean water.

If the radiator is blocked internally, refer to the OEM Manual for information regarding flushing the cooling system.

After cleaning the radiator, start the engine. Allow the engine to operate at low idle speed for three to five minutes. Accelerate the engine to high idle. This will help in the removal of debris and the drying of the core. Slowly reduce the engine speed to low idle and then stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a “comb”. Inspect these items for good condition: Welds, mounting brackets, air lines, connections, clamps and seals. Make repairs, if necessary.

i02335775

Severe Service Application - Check

Severe service is the application of an engine that exceeds the current published standards for that engine. Perkins maintains standards for the following engine parameters:

- Performance such as power range, speed range, and fuel consumption
- Fuel quality
- Operational Altitude
- Maintenance intervals
- Oil selection and maintenance
- Coolant type and maintenance
- Environmental qualities
- Installation
- The temperature of the fluid in the engine

Refer to the standards for the engine or consult your Perkins dealer or your Perkins distributor in order to determine if the engine is operating within the defined parameters.

Severe service operation can accelerate component wear. Engines that operate under severe conditions may need more frequent maintenance intervals in order to ensure maximum reliability and retention of full service life.

Due to individual applications, it is not possible to identify all of the factors which can contribute to severe service operation. Consult your Perkins dealer or your Perkins distributor for the unique maintenance that is necessary for the engine.

The operating environment, incorrect operating procedures and incorrect maintenance procedures can be factors which contribute to a severe service application.

Environmental Factors

Ambient temperatures – The engine may be exposed to extended operation in extremely cold environments or hot environments. Valve components can be damaged by carbon buildup if the engine is frequently started and stopped in very cold temperatures. Extremely hot intake air reduces engine performance.

Quality of the air – The engine may be exposed to extended operation in an environment that is dirty or dusty, unless the equipment is cleaned regularly. Mud, dirt and dust can encase components. Maintenance can be very difficult. The buildup can contain corrosive chemicals.

Buildup – Compounds, elements, corrosive chemicals and salt can damage some components.

Altitude – Problems can arise when the engine is operated at altitudes that are higher than the intended settings for that application. Necessary adjustments should be made.

Incorrect Operating Procedures

- Extended operation at low idle
- Frequent hot shutdowns
- Operating at excessive loads
- Operating at excessive speeds
- Operating outside the intended application

Incorrect Maintenance Procedures

- Extending the maintenance intervals
- Failure to use recommended fuel, lubricants and coolant/antifreeze

i02177969

Starting Motor - Inspect

Perkins recommends a scheduled inspection of the starting motor. If the starting motor fails, the engine may not start in an emergency situation.

Check the starting motor for correct operation. Check the electrical connections and clean the electrical connections. Refer to the Systems Operation, Testing and Adjusting Manual, “Electric Starting System - Test” for more information on the checking procedure and for specifications or consult your Perkins dealer or your Perkins distributor for assistance.

i02184788

Turbocharger - Inspect (If Equipped)

A regular visual inspection of the turbocharger is recommended. Any fumes from the crankcase are filtered through the air inlet system. Therefore, by-products from oil and from combustion can collect in the turbocharger compressor housing. Over time, this buildup can contribute to loss of engine power, increased black smoke and overall loss of engine efficiency.

If the turbocharger fails during engine operation, damage to the turbocharger compressor wheel and/or to the engine may occur. Damage to the turbocharger compressor wheel can cause additional damage to the pistons, the valves, and the cylinder head.

NOTICE
Turbocharger bearing failures can cause large quantities of oil to enter the air intake and exhaust systems. Loss of engine lubricant can result in serious engine damage.

Minor leakage of oil into a turbocharger under extended low idle operation should not cause problems as long as a turbocharger bearing failure has not occured.

When a turbocharger bearing failure is accompanied by a significant engine performance loss (exhaust smoke or engine rpm up at no load), do not continue engine operation until the turbocharger is renewed.

A visual inspection of the turbocharger can minimize unscheduled downtime. A visual inspection of the turbocharger can also reduce the chance for potential damage to other engine parts.

Removal and Installation

Note: The turbochargers that are supplied are nonserviceable.

For options regarding the removal, installation, and replacement, consult your Perkins dealer or your Perkins distributor. Refer to the Disassembly and Assembly Manual, “Turbocharger - Remove and Turbocharger - Install” for further information.

Inspecting

NOTICE
The compressor housing for the turbocharger must not be removed from the turbocharger for cleaning.

The actuator linkage is connected to the compressor housing. If the actuator linkage is moved or disturbed the engine may not comply with emmissions legislation.

1. Remove the pipe from the turbocharger exhaust outlet and remove the air intake pipe to the turbocharger. Visually inspect the piping for the presence of oil. Clean the interior of the pipes in order to prevent dirt from entering during reassembly.
2. Check for the presence of oil. If oil is leaking from the back side of the compressor wheel, there is a possibility of a failed turbocharger oil seal.

   The presence of oil may be the result of extended engine operation at low idle. The presence of oil may also be the result of a restriction of the line for the intake air (clogged air filters), which causes the turbocharger to slobber.
3. Inspect the bore of the housing of the turbine outlet for corrosion.
4. Fasten the air intake pipe and the exhaust outlet pipe to the turbocharger housing.

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Walk-Around Inspection

Inspect the Engine for Leaks and for Loose Connections

A walk-around inspection should only take a few minutes. When the time is taken to perform these checks, costly repairs and accidents can be avoided.

For maximum engine service life, make a thorough inspection of the engine compartment before starting the engine. Look for items such as oil leaks or coolant leaks, loose bolts, worn belts, loose connections and trash buildup. Make repairs, as needed:

- The guards must be in the correct place. Repair damaged guards or replace missing guards.
- Wipe all caps and plugs before the engine is serviced in order to reduce the chance of system contamination.

NOTICE
For any type of leak (coolant, lube, or fuel) clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

NOTICE
Accumulated grease and/or oil on an engine is a fire hazard. Remove the accumulated grease and oil. Refer to this Operation and Maintenance Manual, “Engine - Clean” for more information.

- Ensure that the cooling system hoses are correctly clamped and that the cooling system hoses are tight. Check for leaks. Check the condition of all pipes.
- Inspect the water pump for coolant leaks.

Note: The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and the parts contract.

Excessive coolant leakage may indicate the need to replace the water pump seal. For the removal of the water pump and the installation of water pump and/or seal, refer to the Disassembly and Assembly Manual, “Water Pump - Remove and Install” for more information or consult your Perkins dealer or your Perkins distributor.

- Inspect the lubrication system for leaks at the front crankshaft seal, the rear crankshaft seal, the oil pan, the oil filters and the rocker cover.
- Inspect the fuel system for leaks. Look for loose fuel line clamps and/or tie-wraps.
- Inspect the piping for the air intake system and the elbows for cracks and for loose clamps. Ensure that hoses and tubes are not contacting other hoses, tubes, wiring harnesses, etc.
- Inspect the alternator belts and any accessory drive belts for cracks, breaks or other damage.

Belts for multiple groove pulleys must be replaced as matched sets. If only one belt is replaced, the belt will carry more load than the belts that are not replaced. The older belts are stretched. The additional load on the new belt could cause the belt to break.

- Drain the water and the sediment from the fuel tank on a daily basis in order to ensure that only clean fuel enters the fuel system.
- Inspect the wiring and the wiring harnesses for loose connections and for worn wires or frayed wires.
- Inspect the ground strap for a good connection and for good condition.
- Disconnect any battery chargers that are not protected against the current drain of the starting motor. Check the condition and the electrolyte level of the batteries, unless the engine is equipped with a maintenance free battery.
- Check the condition of the gauges. Replace any gauges that are cracked. Replace any gauge that can not be calibrated.

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Water Pump - Inspect

A failed water pump may cause severe engine overheating problems that could result in the following conditions:

- Cracks in the cylinder head
- A piston seizure
- Other potential damage to the engine

Note: The water pump seal is lubricated by the coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and parts contract.

Visually inspect the water pump for leaks. Renew the water pump seal or the water pump if there is an excessive leakage of coolant. Refer to the Disassembly and Assembly Manual, “Water Pump - Remove and Install” for the disassembly and assembly procedure.

Warranty Section

Warranty Information

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Emissions Warranty Information

This engine may be certified to comply with exhaust emission and gaseous emission standards that are prescribed by the law at the time of manufacture. This engine may be covered by an Emissions Warranty. Consult your authorized Perkins dealer or distributor to determine if your engine is emissions certified and if your engine is subject to an Emissions Warranty.

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