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1 Ton Mini excavators and considerations for machine selection.

Revision: JUL/2024

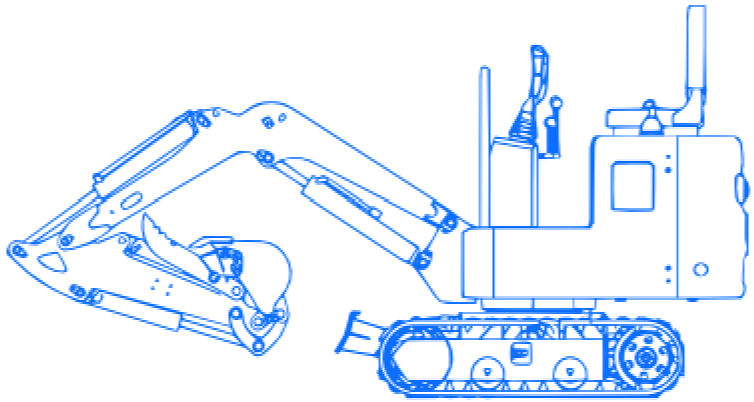
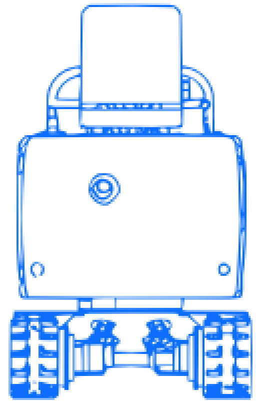
WIP, Not Final.
This document is a working draft at early stages of our research and writing. Content is not poorly organized and has not undergone any proofreading.

For many of us the mini excavators provided by the big brands are simply not an alternative due to their high acquisition cost and our use case. Chinese manufacturers are introducing a wide array of affordable mini excavators that have become a practical and affordable choice. The number of manufacturers and machine variants just add to the confusion of considering a mini excavator. Most of the people looking to buy are not operators or have prior experience with machinery of this kind. We put together this guide to help normal people, independent contractors, property owners looking for something to make their jobs easier.

This guide is not intended to be a buying guide, instead we hope that we can help you learn just a bit more and gain some basic technical foundations so you can make a better choice.

Disclaimer: While we try to be comprehensive, this document is by no means a definitive guide to mini excavators. It is impossible for us to know every single variation out there, nor do we have access to all brands. We did spend a lot of time reading everything we found online, reaching out to manufacturers and diving head down into the online forums. If you find any errors please send us a quick email with your comments.

Some basics!

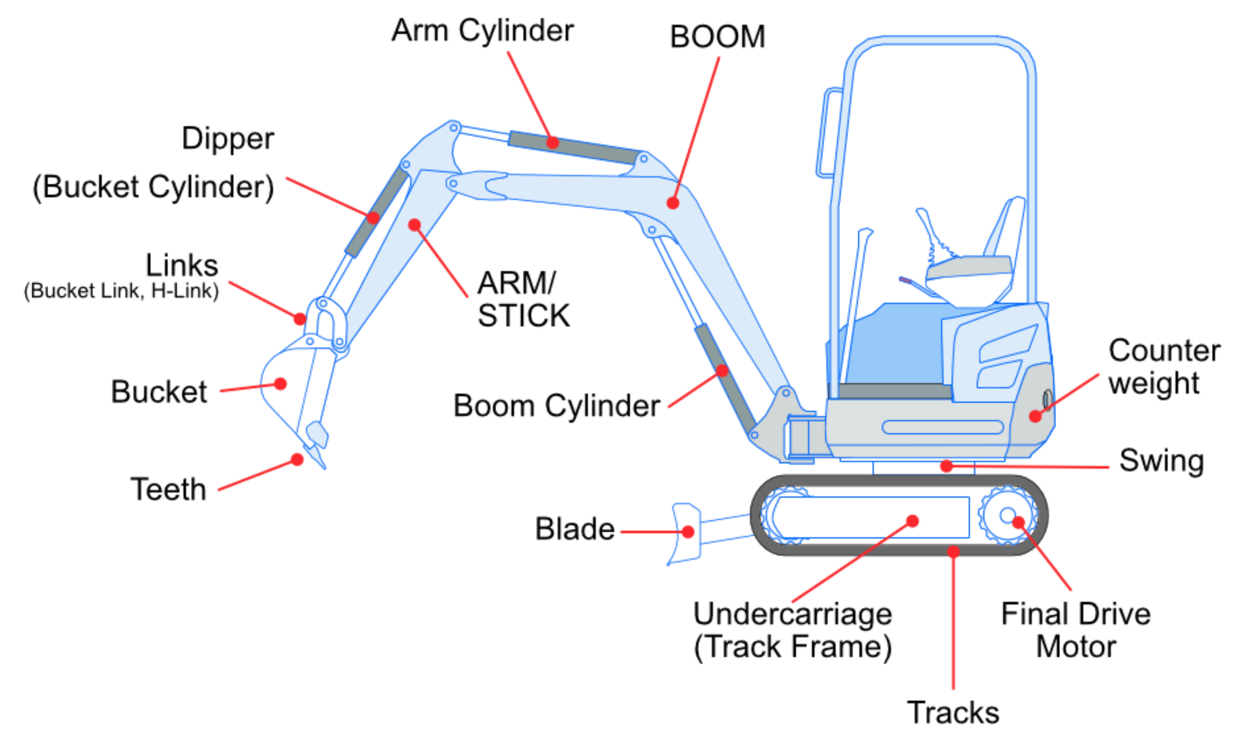



A micro or mini excavator is a category of excavators that are within a particular weight class. A machine that goes all the way to 20,000 pounds may be called a mini excavator, but commonly the category upper limit is 6 tons. For the purpose of this guide audience we will limit the range for practicality to 3 tons. The terms micro and mini are commonly used interchangeably but for us a micro excavator is 1.5 ton or less.

The model name usually indicates the weight class of the machine and not an actual weight. For example "12" in a model number is a 1200kg machine, a "15" is 1.5kg and a "20" is a 2 ton machine, etc (*When we say tons we are always talking about metric tons*). Be certain that when a supplier manufacturer specifies a weight they are listing the weight class and not the actual weight (dry weight). The actual weight of the machine is usually under its weight class.

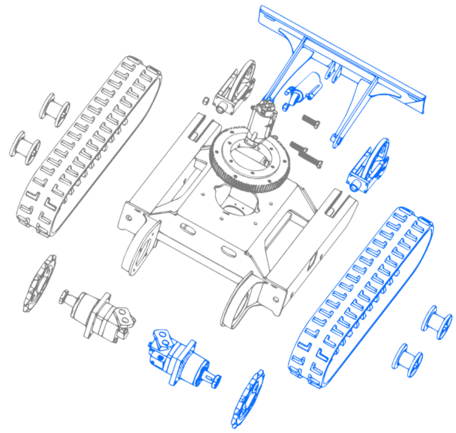
The weight class together with engine horsepower are two important factors that determine the type of regulations and standards a machine must meet to operate by law in the US and Europe. In particular, is it more than 20 hp or less? As we dive deeper we will learn that some of the design choices on these machines are driven by the need to stay within a particular regulatory framework.

Let's start with some basic concepts and walk our way around a common mini excavator.



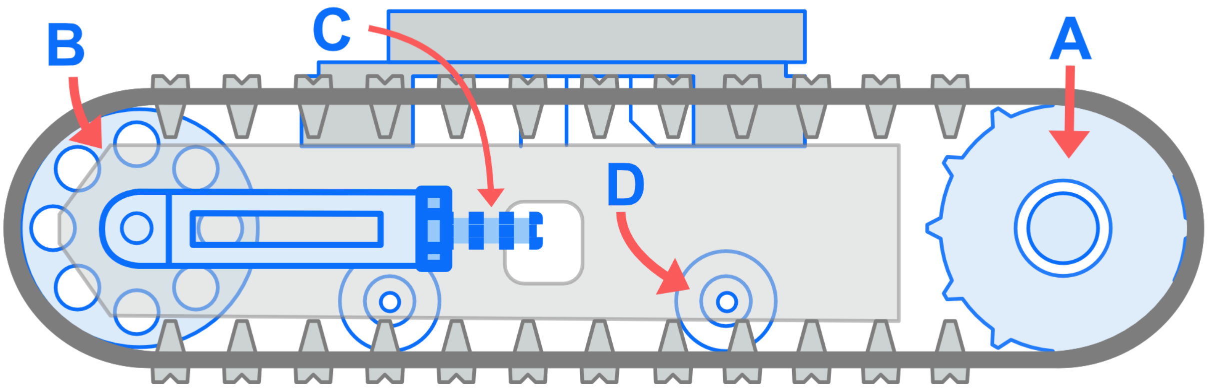
Major components of a mini excavator.

Undercarriage



The chassis that holds the tracks and the machine is called the undercarriage.

The undercarriage has your track assembly, your swing motor and slewing gear, etc. The track assembly and travel motors move the rubber tracks and the swing hydraulic motor spins the machine around its axis by turning on the slewing gear.



The **track assembly** are the components on the carriage frame that hold and operate our tracks (rubber crawler tracks). The **drive sprocket** (**A**) is powered by our travel motors and moves the track on the assembly. The sprocket is attached to our hydraulic motor shaft with a cotter pin and castle nut. The motor shaft has a keyway (square key/parallel slot, tapered shaft) that drives the sprocket. The **idler wheel** (**B**) holds the track on the other end. The idler pushes outward adding the required tension to hold the track in place. The idler is pushed by a **tensioner** (**C**). In basic machines the tensioner is a simple threaded rod that we turn to move the idler in or out, the idler may include a spring. Other models use a cylinder where grease under pressure pushes the idler in or out. Finally the two bottom **track rollers** (**D**) keep the track aligned and provide the structural support for the track assembly.

The first important consideration of the carriage frame is the steel gauge. Some machines will use for example a gauge 3 (6mm) which may prove to fatigue and break easier than you may think. For example a chassis made by RIPPA uses a thicker gauge ranging from gauge 0 (8mm) up to (3/8", 10mm).

The second thing is reinforcement of the frame, welding quality and structural rigidity. Here we are looking for double walls, bends, support wedges, etc.

Our friends at RIPPA use Kawasaki arc welding robots to ensure professional welding and integrity of welds. My welds are good but that Kawasaki robot just makes some beautiful seams. That's the sort of thing you notice on a good build. (PS I lied, my welding skills are as novice as it gets.)

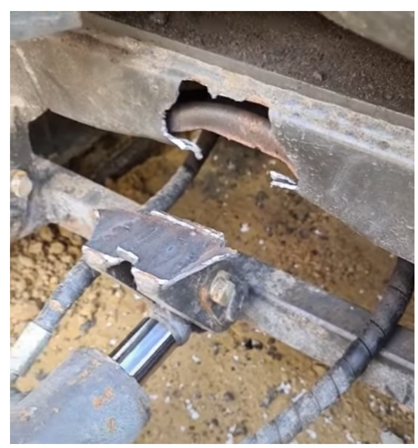


Image: @everydaywithmenick, YouTube

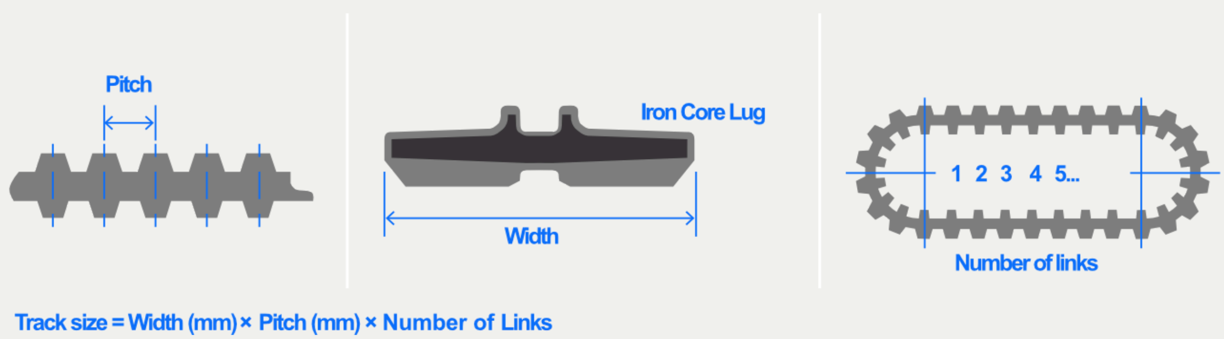
The basic frame is a fixed chassis and then some machines may offer "**telescopic tracks**". A telescopic chassis has hydraulics pistons that allow it to expand the tracks outward or tuck them in. Sadly telescopic tracks are one of those features that is poorly documented by manufacturers. You have to be careful with this feature as in reality some telescopic tracks only add around 3" to 4" to the total base width, or about 2" on each side. For telescopic tracks to make a difference on stability, change the lateral tilt angles or help distribute the weight they need to extend out from under the chassis, otherwise the feature becomes a gimmick. In some machines the telescopic design is very primitive which subtracts from the structural integrity of the machine and durability.

Crawler Rubber Tracks.

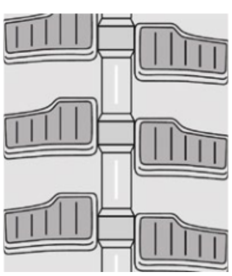
These excavators use crawler tracks that are made of an iron core lug center and reinforced steel cables that run along the surface of the track to provide reinforcement.

A track is measured by the width of the track shoe, the pitch (distance from one iron core to the next), and the number of iron lugs (links). A common track found in mini excavators is 180mm x 72mm x 37.

72mm	180mm	37

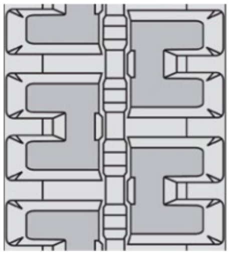


The molded rubber protrusions (track shoes) are designed for different types of surfaces and operating capacity.

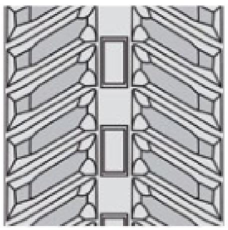


A staggered block pattern track is a general purpose track with no directional requirements. It operates smoothly on hard surfaces, causes minimal ground disruption to finished lawns, and has an acceptable performance on sand, clay, dirt, mud, gravel, and asphalt.

This track is not recommended for snow or rocky conditions.



A "C" pattern track is a type of staggered pattern that provides improved performance on clay, mud, gravel and sand compared to a regular staggered pattern.

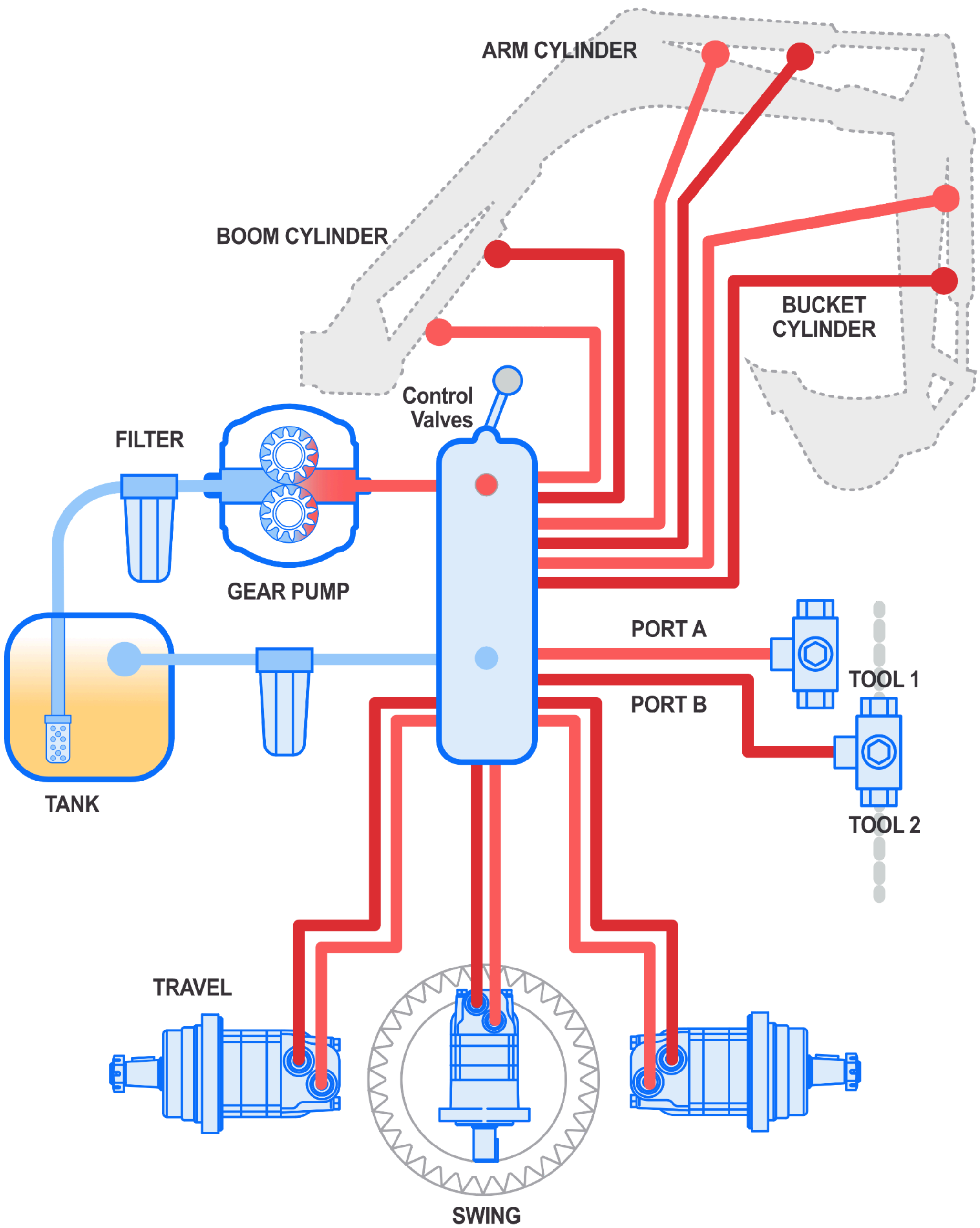


The v-shape pattern track is commonly used in agricultural applications and provides better traction in muddy and soft dirt. The v-shape pattern moves the mud to the outside and thus it must be mounted facing forward (directional). If mounted in the wrong direction mud will be directed under the machine. This pattern is rough on lawns.

The lifespan of a track is listed in terms of operating hours. The tracks installed in these mini excavators are general purpose tracks and are not rated (in the machines we have seen) to operate on rocky surfaces or over sharp debris. Continuous operation in these conditions will reduce the tracks' lifespan.

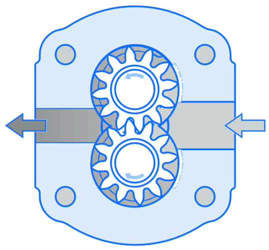
Hydraulics

The hydraulic system is what defines these excavators. We made the following diagram to show you the basics of the system.



There are four main components in the hydraulic system. The main pump, the swing motor, the travel motors, and the DCV (Directional-Control Valves) control block (manifold) (our control sticks!).

The heart of the system is the geared pump which as the name implies pumps the hydraulic oil and creates the flow that pressurizes the lines. The flow of oil from the tank to the pump is called the "suction".



Anything between the tank and the pump's inlet is said to be on the "suction side" of the system. Since the hydraulic oil is pulled in at the inlet with little or no resistance this side is also called the low pressure side. The inlet at the pump is called a suction port or low pressure port. On the outlet side the flow is exerting forces; the flow restriction and build up of oil volume in cylinders and motors creates pressure on the lines. We say that things on this side are on the "pressure side" and our outlet is called the pressure port.

From our pump the flow of oil makes it into our Directional Control Valves. The control block is a set of valves stacked together. Each valve has a lever (or pedal) and controls one cylinder or motor. The lever directs flow out on one port to the cylinder/motor and returns on the other port. Moving the lever in the opposite directions reverses the flow to go out on the other port instead. This change of flow makes the motor or cylinder move in the opposite direction.

Oil returned to the DCV is piped back to the oil tank (shown in blue in our illustration). We call this the "return side" of the system and we have "return hoses", "return filters", etc.

As you can see our hydraulic oil is constantly being circulated around the system forming our **Open Center Hydraulic Circuit**.

Since our hydraulic pump is driven by our engine, looking at the nominal rpm of the engine will automatically give you the operating range of the hydraulic motors, pumps and other components found in a mini excavator. For example engines like 192F, LL360, BS XR 25T2, D722, D902 all have a nominal rpm from 2000 to 2500 and max at 3000 to 3600 rpm. With this information we now know to look at hydraulic components with a nominal displacement within that rpm range. Mini excavators on the 1 ton weight class pretty much have hydraulic systems designed for 2500 rpm with some models pushing to 3000 rpm.

A side note on hydraulic system sizing

We need to talk a bit about hydraulic system sizing and the relationship between engine and pump. A hydraulic system is basically (oversimplification) designed to sustain a given flow rate (displacement x efficiency) which in turn is associated with the pressure (bar) it can sustain. The designer will add all the forces that the machine is expected to support (tracks crawling, swivel of the chassis, and your boom/bucket). The engineer comes up with a number, for example at any given time this machine needs to sustain a 2500 PSI (172bar) and he/she adds a safety margin and designs a system for 3000 PSI (~200bar). The machine will have components that can sustain 2500 PSI and withstand outbursts of 3000 PSI. A gear pump (same for motors) will have the nominal rpm at which it should be operated and the documentation will also have a Pressure-vs-RPM table. They select a pump that can sustain 2500 PSI within its nominal operating RPM. The Pressure-vs-RPM table tells them that they need 2000 RPM to sustain that pressure. Now we look at the engine's power curve and find a motor that can sustain 2000 RPM within its nominal operating range. The pump they selected will have a max continuous pressure. That max pressure will dictate the selection of the rest of the components and the RPM at which the engine can operate. The safety margins used vary by manufacturer but be warned that it is always good to check the ratings of all the components to determine your machine's actual operating rating.

At 2500-3000 rpm range we are looking at components and parts that operate at around 2900-3000 psi but since all these components are metric it is good to rewire your head to pascals or 20 mPa or 200 bar. At 20 mPa the system is considered a low pressure hydraulic system.

***Warning**: While it is called low pressure, 3000 PSI is very serious. Hydraulic oil injection is an incident where minuscule droplets of hydraulic oil penetrate your skin due to the pressure from a pinhole leak on a hose, a major failure or you being a dummy and putting your face or hands over a leak on a pressurized system. If this happens you need to go to the emergency room, If left untreated you may end up with an amputated limb or even die. The bottom line, be smart, use common sense!*

A machine can have brand name components like Danfoss, (Eaton Hydraulics was acquired by Danfoss), Parker, Rexroth/Bosch, but mainly they will be equipped with a white label chinese component. Luckily for us, the main white label Chinese motors and pumps are intended as Danfoss or other major brand replacements or clones.

For example, Danfoss has the following series of hydraulic motors OMT, OMR or OMV. Each of these series will have a white label counterpart using a similar series name like BMT, BMR and BMV.

There are four main characteristics that defines a motor or pump type:

- The displacement (flow) for each revolution (cm3/rev, 1mL = 1cm3).
- The shaft that is used to drive a track sprocket, swing the machine or connect the pump to the motor.
- The dimensions and screw holes of the mounting flange/face.
- The type, dimensions and threads used by the hydraulic hose connections.

Thankfully there are a couple of industrial standards used by the manufacturers of these components and hoses.

A side note on threads

Let's pause here and learn a bit about these standards. The most important thing relating to fittings, screws and nuts is the thread used. The diameter and length are basic elements of the dimensions that we will not discuss here for sake of brevity. A thread is either on the inside of a hole or nut (internal) or on the outside of a fitting/nipple or screw (external). The V groove that creates the thread is defined as the thread angle. The distance from the middle of one groove to the same point on the next is the pitch of the thread. A common thread is parallel (straight) but they can also be taper. A standard defines the exact characteristics of each thread type (mainly pitch, diameter and angle). Threads on screws, fittings and connections follow one of these standards:

ISO 261/262, Metric Threads Wikipedia
ISO 228, BSP British Threads Wikipedia

ANSI/ASME B1.1, Unified Thread Standard (US/Canada) [Wikipedia]
NTP, National Pipe Thread (US) [Wikipedia]

For us in the US, ASME B1.1 and British BSP ISO 228 tend to cause problems and confusion. A 1/4" ANSI and a 1/4" BSPP look identical to the untrained eye and in most cases it will fit, yet differences in angle and others would cause leaks and will not have the matting integrity. **When it comes to hydraulic systems the "it fits rule" does NOT apply!**

In most cases a given model of a motor has a variant for each of the major standards. You will have a variant with oil ports for metric threads, one for british threads (G threads) and ANSI/ASME for the US. In other words you will have a US/Canada version, a British version and a DIN/Metric/German version, the same thing goes for the shaft. Big brands offer all sorts of combinations but those three are the common ones you can readily find. Things like SAE J514/JIC and others are not really used on this type of machine. When you see the term "Metric" used to describe a part you can safely translate that to "DIN".

A Chinese mini excavator will likely (99.99999%) use "Metric" (DIN) variants of everything (including hoses, fittings, etc). The only exception that you may find is with ball-valves (cut-off, 3-way, etc) mainly used for auxiliary tools which may use British (BSP) and pumps that may have SAE ports (inlets/outlets).

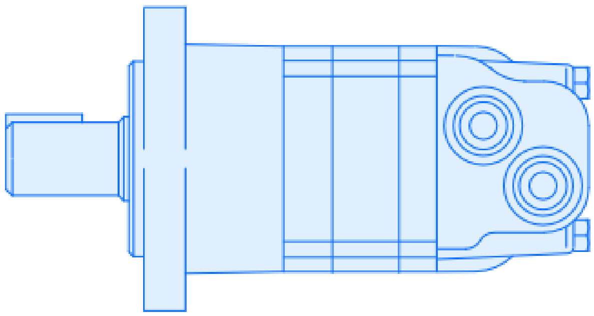
Before we look at each component of the hydraulic system lets talk a little about the type of pumps and motors. Hydraulic motors come in different types.

The first type we have are geared pumps, since these are easier to identify we will not say much about them for now. Geared pumps have a directional oil flow, one port is an inlet and another port is an outlet. Since they are attached to a gasoline engine a pump has to match the engine rotation in relation to the flow desired.

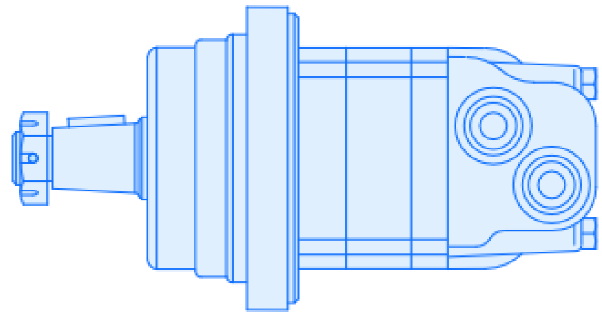
Then we have low speed/high torque orbital motors. The word "orbital" just means we have an external shaft that spins on its axis and the rotation is determined by the direction of the oil flow (bi-directional). In this class of motors we have different designs, just because nothing can be simple!

> The **Gerotor** motors are the simpler, smaller and most affordable design. Their simpler design makes them quite reliable. This motor uses a rotor (remember Mazda's rotors!) to move the hydraulic fluid and build the required flow. The **Geroler** motors are siblings of the gerotor but with added rollers around the rotor. More expensive than a gerotor but are capable of just a tad more torque.
>
> Then we have the valve design, the **Spool Valve** design and the **Disc Valve** design. The spool valve design is simpler and more affordable, yet the disc valve design has better performance and is able to maintain a steadier flow/pressure even at low rpms. In a disc valve motor the ports are always at the end, while on a spool valve the ports will be near the drive shaft to the front.

In mini excavators an orbital motor (geroler motor used for travel and swing) comes in two main flavors.



A standard motor has the mounting flange on the front. The shaft can be smooth with a keyway or use splines (6, 9 to 11 teeths).



A wheel motor used on tracks has the mounting flange towards the center and usually has a tapered profile on the shaft end. They use a pin and castle nut with a keyway on the tapered shaft.

These types of off-brand hydraulic motors have common names among manufacturers.

BM1	This is generally the smallest gerolor motor you can find for machinery and agricultural uses. It uses spool valves.
BM2/BMR/OMR	This is a gerolor motor with spool valves. This model is commonly used as a swing motor in the 1-1.5t machines. The BM2 and BMR are the same family of motors
BM5/BMS	This is the gerolor motor with disc valves. We used to see this one use for travel motors on early generations of mini excavators. The BM5 and BMS are the same family of motors.
BM6/BMT/OMT	This is the big brother of the BM5. Same concepts but rated to handle greater loads/torque. This is the motor commonly used for travel motors. The BM6 and BMT are the same family of motors.
BMV/OMV	This is the heavyweight of gerolor/disc valve motors (for the purpose of this guide). It's generally used on bigger 2-3t machines.

These white-label motors are sold with common model numbers. We will see things like "BM6/BMT BMV" with a number like "306", "315", etc. That number tells us two things. The first number "3" (or "5") is the gear module, the remaining two digits are the displacement capacity. For example a "BMV-315" is a motor with a rated displacement of 15 mL/rev and a gear modulus of 3. For our conversation all we need to know is that a higher module means thicker and bigger teeth which translate to more torque.

One added bonus is that, unlike big-name excavators, these micro excavators use standard motors common in various machinery and applications such as lift gates, log splitters, shop cranes, tractors, forklift, and skid steers, making them more common than you might have guessed.

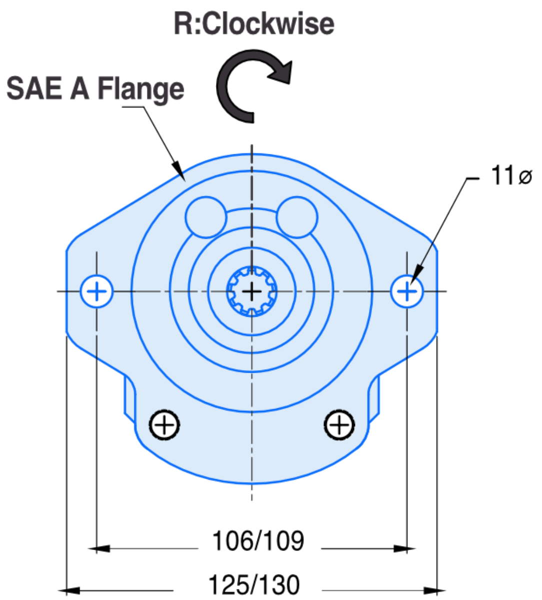
Main Pump

Attached to your engine we have the main hydraulic pump. This motor pressurizes the hydraulic fluid circulated in the excavator. This pump is a Group 2 external gear pump (fixed positive displacement gear pump).

These pumps are rated by their displacement force (flow) measured in cubic centimeters per revolution (cm3/rev) or in mL per revolution (both units are equal) (for us in the US we can think of Gallons per Minutes as an analogy.) The only job of a pump is to sustain a rate of flow. The pressure occurs when flow meets resistance inside cylinders and motors. The pressure rating on a pump is strictly the max pressure it can withstand (nominal and max), the resistance it encounters will dictate the actual pressures exerted on the system.

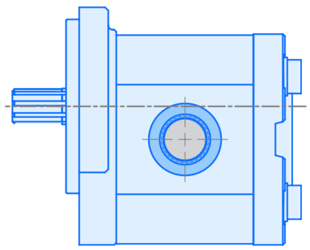
WARNING: While white-label gear pumps from China usually show displacement values at 2500 rpm not all manufacturers will use the same rpm to compute their rated displacement.

Notice that this pump is directional, it needs to rotate in a particular direction to move the oil from the inlet to the outlet. The inlet port will have a larger diameter than the outlet port. The rotation will be clockwise (right) or counterclockwise (left). In general when facing the shaft and flange in a clockwise pump the outlet is on the right side. Basic mini excavators will use a clockwise (right) pump.



A common standard used by the pumps on these excavators is SAE J744. SAE J744 is a standard for HYDRAULIC PUMP AND MOTOR MOUNTING AND DRIVE DIMENSIONS. In these standards we find exact mechanical dimensions and tolerances for mounting flanges (4 screw square mount, or a two screw oval mount) and the shaft dimensions and types (threaded bolt, keyway, and splines).

Each different mount in SAE J744 has an identification code for example "A-A", "A", "B", etc. In the 2500rpm/20mPa range we usually see SAE J744 "A". When looking up specifications or documentation this may be shortened to "SAE A" or they will say "SEA A Falange".



The pump has a splined shaft also defined in SAE J744 A, The common pump on 1 ton machines is a SAE “A” 9 teeth (16/32 DP) spline shaft. ANSI B92.1 will give you the dimensions you need for the spline and mating spline. The shaft is connected to the motor with a plum blossom coupling (coupling sleeve).

NOTE: The presence of a gear pump will mean (with 99.999% certainty) that you have an Open Center Hydraulic System. For gear pumps to work on a closed center system we need additional components that are beyond the price point and design of 1 ton mini excavators.

While orbital motors have a more standard nomenclature that makes them easier to identify, the geared pumps have way more variation on product names and nomenclature.

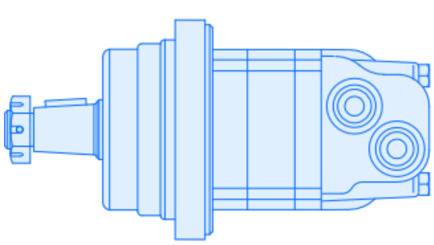
Similar to orbital motors a product number may use three digits to identify a series's module and displacement. For example "306" is a 3 gear modulus with 6 mL/r displacement. Generic white label pumps that start with "CB" usually have a letter on their second segment right before the 510 or 315. For example "E306", that letter is the pressure range of that series. A common example we found is "E" for 16mPa, "F" for 20mPa, "G" for 25MPa and "H" for 30 or above. Product numbers that start with "PGP" are sold as replacements for Parker PGP 500 series.

A pump on the 20Mpa range with SAE J744 A mounting is usually found with SAE threaded ports (ISO 11926-1) or "standard ports". The inlet is SAE 12 (Dash -12)(1 1/16–12UNF–2B) and the outlet SAE 10 (Dash -100(7/8–14UNF–2B) with O-rings. (still researching this)

But of course, it's not that simple! On the other side of the Atlantic, we find metric threads using M22 and M18, respectively, and British Standard Pipe Parallel (BSPP) with G 1/2 and G 3/8.

Sadly if the User Manual that came with your machine is a minimalistic excuse for a manual, chances are that the only option you have in identifying a pump is to take some measurements and check them against technical specifications from pump manufacturers. Thankfully with the RPM of your engine and the displacement rating of the travel motors you should be able to narrow down your search fairly fast.

Travel (Orbital) Hydraulic Motors



The travel motor moves the tracks of the excavator. This motor is called the "final drive" or "track drive". This type of motor is called a Slow Speed Geroler Orbital Hydraulic Wheel Motor, where "Wheel Motor" is the term you want to google for.

We can make the following educated guesses about a travel motor found on an affordable excavator.

The motor will be a BM5/BMS, BM6/BMT or BMV series. The shaft will be tapered with a parallel square key and a slotted castle nut.

Since these white label motors come in fairly standard options at 3000rpm we are looking at a 20 to 25mPa motor for example a BMV-315, BMT-315 or BM6-315. Like we mentioned before on a BM6/BMT and BMV motors their number is their nominal displacement, for example a BMV-315 is 15 cm3/rev motor.

The shaft seal is a common failure point on a wheel motor. Excess in operating pressure will start showing up as leaks on the seal and eventual failure of the seal. Factors that contribute to seal failures are:

- High hydraulic oil temperatures.
- Pressures that exceed the seal's rated capacity due to high flow rate or too much oil (volume).
- Damage or worn parts inside due contaminants cause an unexpected increase of oil flow to the low pressure side.

All motors and cylinders have internal leakages, some of the oil just leaks its way right thru to the low pressure side. Motors have cavities to handle this extra flow on the other side and rely on the strength of the seals to hold any build up of pressure. These motors may also come with a case drain. The case drain is a larger cavity meant to be connected to the "case drain circuit" (drain lines) that will drain excess volumes/pressure back to the hydraulic tank. If the motor has a case drain it will say it has a "drain port". The drain port is usually much smaller than your A/B ports.

Having drain ports on the motors of a machine is a good feature, even in the absence of a proper case drain circuit. A case drain means that we have a larger cavity to handle fluctuations of oil volume without building excess pressure on the seal. In addition the case drain provides a place for contaminants to go. We can also use them to bleed the system and troubleshoot.

Swing Drive

The swing drive is the gear assembly that rotates the body of the machine. The hydraulic swing motor spins the machine around its center. It has a gearbox with a drive gear. The drive gear rotates along a large slewing ring (gear) and thus rotating the body. The guys at HRPARTS.com have an exceptionally good explanation of swing drives that I invite you to check out.

These machines commonly use a white-label BM2/BMR orbital hydraulic motor rated as 315. This motor is a simpler spool valve design which is perfectly fine for its intended purpose.

Valve Control Block

The sticks that control the movements of the excavator use Directional Control Valves (DCV) and many people call them spool valves. The control block is a set of spool valves stacked together, this is called a Sectional or Modular DCV with an open center hydraulic circuit. In an open center system the hydraulic oil is always flowing in the circuit.

Each component (cylinders, motors) driven by hydraulic oil is connected to one valve. Each valve has a control lever that moves a spool (pin) inside which in turn directs the flow to one of the two ports ("Port A" and "Port B"). Each DCV in the block is called a "working module" or "working section".

A working section used on these machines uses a manual three-way spool design (neutral, lower and raise positions) and uses direct control for the spool (lever directly controls the spool).

Usually in these machines we have a single end section that acts as our inlet/outlet module for the entire control block. The inlet is a larger hose that is connected to the main pump with a return line usually under that takes the oil back to the tank.

In these excavators the end section will also have a pressure relief valve. The relief valve handles excess pressure in the block which in turns releases oil back to the oil tank or bleeds oil.

To-Do (researching part manufacturers)

Oil Tanks (Reservoirs)

A hydraulic oil tank needs to hold enough oil to sustain the oil volume used to build the pressures in the system. The tank is never filled to the top to allow room for the oil to flow back and handle excess pressures. As a general rule the tank volume is twice the flow rate of the system.

A tank can be built of steel, aluminum and polyethylene plastic. Steel is the most common tank found. Steel is inexpensive (cost less than plastic) and can help dissipate heat better. Some cons of steel tanks are: they add weight; it is not uncommon to find inside welding slag, metal shavings, paint chips, etc; they are susceptible to moisture condensation and rust. The polyethylene tank can have more practical shapes and weigh much less. They are much less susceptible to moisture but sadly provide little heat dissipation. With that said be careful with steel tanks, they are the defacto on 1 ton machines but not necessarily because it is a good tank, but because it is cheaper and a factory usually builds them themselves which is not necessarily a good thing in terms of quality.

The tank has an inlet and outlet. Your pump pulls the oil from the inlet or intake port and once again we call this the suction port. The outlet is where oil is returned to the tank and we call it the return port.

The suction port usually has a suction strainer inside the tank or a suction filter (regular hydraulic oil filter) connected outside (or both).

A good machine will have a return hydraulic oil filter connected to the return port.

A good tank includes internal baffles (walls) that keep the returning oil from flowing directly to the outlet port and improve heat dissipation. It will also include a larger port or plate to clean the tank and at minimum a drain plug.

The hydraulic oil level is measured by either a sight glass eye or a level. The sight glass eye is mounted directly into the tank and its center points to the oil level the system was designed for. The level is a thermometer looking glass/plastic pipe mounted vertically usually near the tank and connected to the tank with small hoses. Fancy levels also indicate the oil temperature. These levels are more susceptible to trapped air bubbles, they may be harder to read and the level shown may not correspond to actual oil levels in the tank. On the other hand a sight glass lets you see the oil in the tank and allows you to see the amount of bubbles and froth both indicators that we have problems in our hydraulic system.

Hoses, Fittings and Adapters

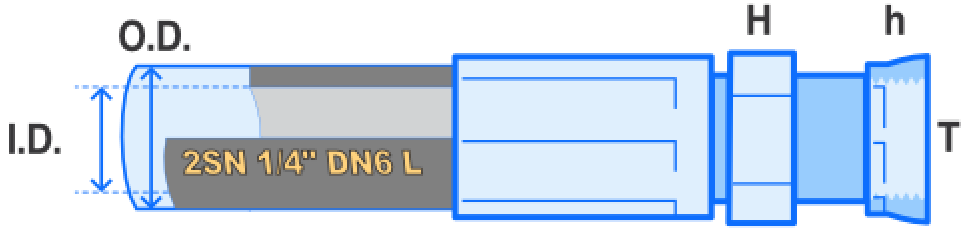
These excavators use standard 1SN and 2SN hoses, nothing special here. Your local hydraulic shop or tractor should have everything you need to replace and service these hoses.

DIN EN 853 1SN SAE100R1-AT	Single layer of steel wire braid reinforcement. Type: abrasion resistance. Non-Skive. Normal Bend-Radius. Min rated pressure of 20 mPa (3000 psi).
DIN EN 853 2SN SAE100R2-AT	Two layers of steel wire braid reinforcement. Type: abrasion resistance. Non-Skive.

Normal Bend-Radius.
Min rated pressure of 20 mPa (3000 psi).

Hydraulic hoses are sized by their inner diameter (I.D.), flow rate and fluid types. The fittings/adapters are seized by the hose outside diameter (O.D.).

You will find the inside diameter printed on the hose. For example a "DN06" is a 6mm ID hose or 1/4". Most hoses will also have their diameter in inches printed on the hose. The type of hose will also be printed on the hose, for example "2SN" or "1SN" (SAE100R2, SAE100R1).



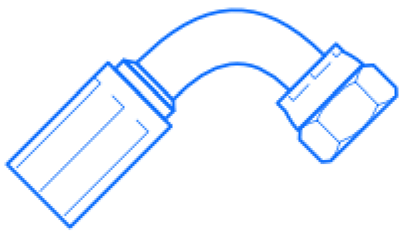
The I.D. can be specified as inches be a fraction or a decimal like 1/4 or 0.25, in millimeters as 6.4mm (1/4). The markings "DN" stand for diameter nominal (Nominal) size notation. The letters "DN" are followed by the nominal diameter in mm. For example "DN6" means 6mm of nominal diameter. We find "DN" on metric hoses using the DIN 2353 standards. A SAE hose will use a dash size (SAE size) notation. A dash is a count of 1/16ths, for example a 3/4" I.D. is written as -4 (notice the dash). British hose will use the "G" notation.

Common hose sizes used in mini excavators.			
I.D. mm	**I.D. in**	**DN/Nominal**	**Dash/SAE**
6 / 6.3	1/4	DN6	-4
8	5/16	DN8	-5
10	3/8	DN10	-6
12 / 12.5	1/2	DN12	-8
16	5/8	DN16	-10
19	3/4	DN19	-12
25	1	DN25	-16

A DIN hose may be "light" or "heavy". A "light" hose is identified by an "L" or "I.RH" (*"S" or "s.RH" is heavy duty*). If you recall, we mentioned that at 3000 psi the system is considered a low pressure system so our hoses and fittings are "light".

Is recommended that a hose should be rated to withstand 33% above the nominal operating pressure of the system. For example if our mini excavator operates at 20mPa we want a hose rated at around 26.6 (20 x 1.33) mPa or 3770.98 psi.

The reinforcement used on a hose changes their outside diameter (O.D.) (how thick it is). A fitting for a DN8 hose "light" is smaller than one for a "heavy" hose.



The fittings used in 1 ton machines are DIN 3902 straight threads with a 24° seal angle with a common thread pitch of 1.5 mm (distance between crest). In the hose ends we find DIN 3902 DKO crimped fittings with O-rings. These DIN fittings are called "metric" fittings or "german" fittings.

We still need to identify fittings since your machine may use other types of fittings that are not DIN 3902. For example sometimes a machine will be fitted with a cut-off/3-way valve that uses BSP threads or a machine will have a pump with SAE threads. We will not cover how to identify fittings since there are plenty of good videos and guides on the internet that will teach you how to identify a fitting or port threads.

Common DIN 3902 threads used...			
Hose O.D.	Thread O.D.	Hose O.D.	Thread O.D.
6mm (1/4")	M12 x 1.5	15	M22 x 1.5
8	M14 x 1.5	18	M26 x 1.5
10	M16 x 1.5	22	M30 x 2.0
12	M18 x 1.5	28	M36 x 2.0

Engine

The de-facto engine in 1 ton machines is a Briggs & Stratton XR 25 (XR2100), a 13.5 HP air cooled gasoline engine. The beloved Briggs Stratton brand is actually owned by Jiangsu Nonghua Intelligent Agriculture Technology (China) which also owns All-Power, Gentron, Murray, Brute, Snapper, Diamond, PowerBoss and other brands under the umbrella of JD North America. The Briggs Stratton XR 25 is also sold as All-Power JD420 yet listed at 15hp instead of 13hp. Clones of the JD420 are also sold by other manufacturers in China and here in the US we have Harbor Freight's Predator 420cc 13 HP Horizontal Engine (item 69736 or 60340) (these engines can be made by Rato or Loncin). At a nominal RPM of 2800 this motor can produce 8.2 HP and 20.85Nm (184.5lbin) of torque.

We have machines with a similar air cooled diesel counterpart the Perkins 402D-05, which has lower nominal RPM listed at 10HP with EPA certification. Next we move up the scale with a Kubota D722 diesel engine designed in Japan. This is a water cooled engine rated at 19.90HP but with similar RPMs to the XR 25. A machine with a Kubota D902 is officially considered an Industrial/Agricultural tractor.

Other markets get non EPA certified engines like the 192F which is a white label diesel engine made by many manufacturers but can not be imported in the US. Other common variants they get are Laidong engines like the LL380, LL480, etc.

Regarding the choice between gas (B&S XR 25) and diesel (Kubota D722) engines, we suggest being practical, as the decision is not straightforward.

When we covered the hydraulic system we highlighted the role of the engine RPM as a condition of our hydraulic system. Chances are that your machine will keep the same hydraulic components regardless of which engine you choose. In this case the hydraulic pump will likely be rated at nominal 2500 RPM and thus the engine you choose will be forced to operate at 2500 RPM regardless if it's more capable.

On these small machines the main diesel engines (EPA certified) are a Kubota D722 or a Perkins 402D-05. When you look at the power curve information from the manufacturer for the D722 you see that its nominal RPM is just 2600 RPM yet in our experience it adds almost $1k to the price of the machine. The 402D-05 is actually a smaller air cooled diesel engine rated at 10hp.

A more capable engine will only affect the hydraulic performance if the hydraulic components are also upgraded.

In these small machines a diesel engine is mainly a conversation of fuel efficiency, while noise and temperature (water cooler) may be a tad better. Some diesel machines have better temperatures mainly because of the placement of exhaust and fuel tank and not because of actual engine difference, at least not in these small engines.

Attachments and Tools

	A standard general purpose digging bucket has teeths and it is used for trenching and digging. The teeths are either welded or screwed to the bucket. Machines come with one standard bucket usually already attached to the arm or you may have to install it when delivered. They come in different sizes but it's common to see a 16" bucket (400mm) or a smaller 300mm (11.8"). The volume of dirt/material that fits in a bucket is the measurement used to describe the size of a bucket. When reading the specifications for a machine the volume is indicated as cubic meters. For example a common bucket is 0.025 m3 or 0.030 m3.
	This narrow bucket is a trenching bucket. We use it to dig small trenches for things like pipes, etc. A common offer is a 200mm or about 8 inches wide.
	This bucket is called a grading (ditching) bucket. It has a flat edge with no teeths and it is used for scooping loose material, cleaning and grading. It comes in many sizes but the more common ones are 500mm and 600mm or 19.5" and 23.5".
	The Jack Hammer or "Breaker" is a hydraulic hammer used to break rocks and concrete. This may be the most expensive attachment but by all means the hammer turns your mini excavator into a monster. Depending where you source the hammer you can get one from around $500 to $800 plus shipping. The hammer uses nitrogen gas for its shock absorber and each model has a particular requirement of gas volume. A hammer for a 1 Ton machine requires around 13 to 15kg/cm2 of gas. You need a meter to measure the gas level and replace as required. RIPPA hammers come with a gas tank and all the tools you need to operate this baby.

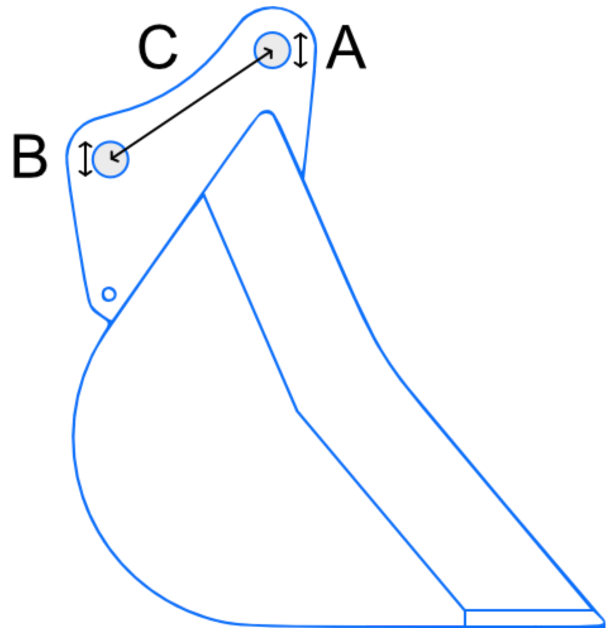
	The rake is used to loosen the top soil, remove vegetation from top soil, and separating rocks from soil, etc. If you have land or a farm this can be quite useful.
	A quick hitch (non-hydraulic) allows you to change attachments more easily. The hitch is attached to the arm. To add a bucket or attachment we turn a screw that slides the u-shape catch onto the pins of the buckets/tools. To release you just unscrew. Using a battery impact driver you can change a bucket in just a few minutes. The versatility of a hitch will depend on what kind of connections you have for the attachments that need hydraulic lines. Must machines have screw fittings so changing tools means unhooking the hydraulic lines. You may want to consider adding quick-disconnect fittings to your auxiliary hoses.

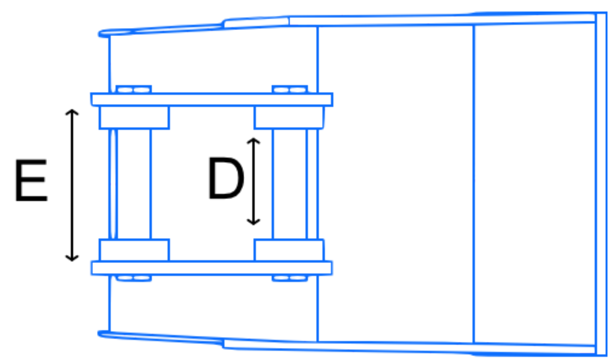
Sizing buckets and attachments.

Buckets and tools are not universal, however many of the micro excavators (1T to 3T) usually stay within a given set of dimensions which allow tools to fit multiple machines.

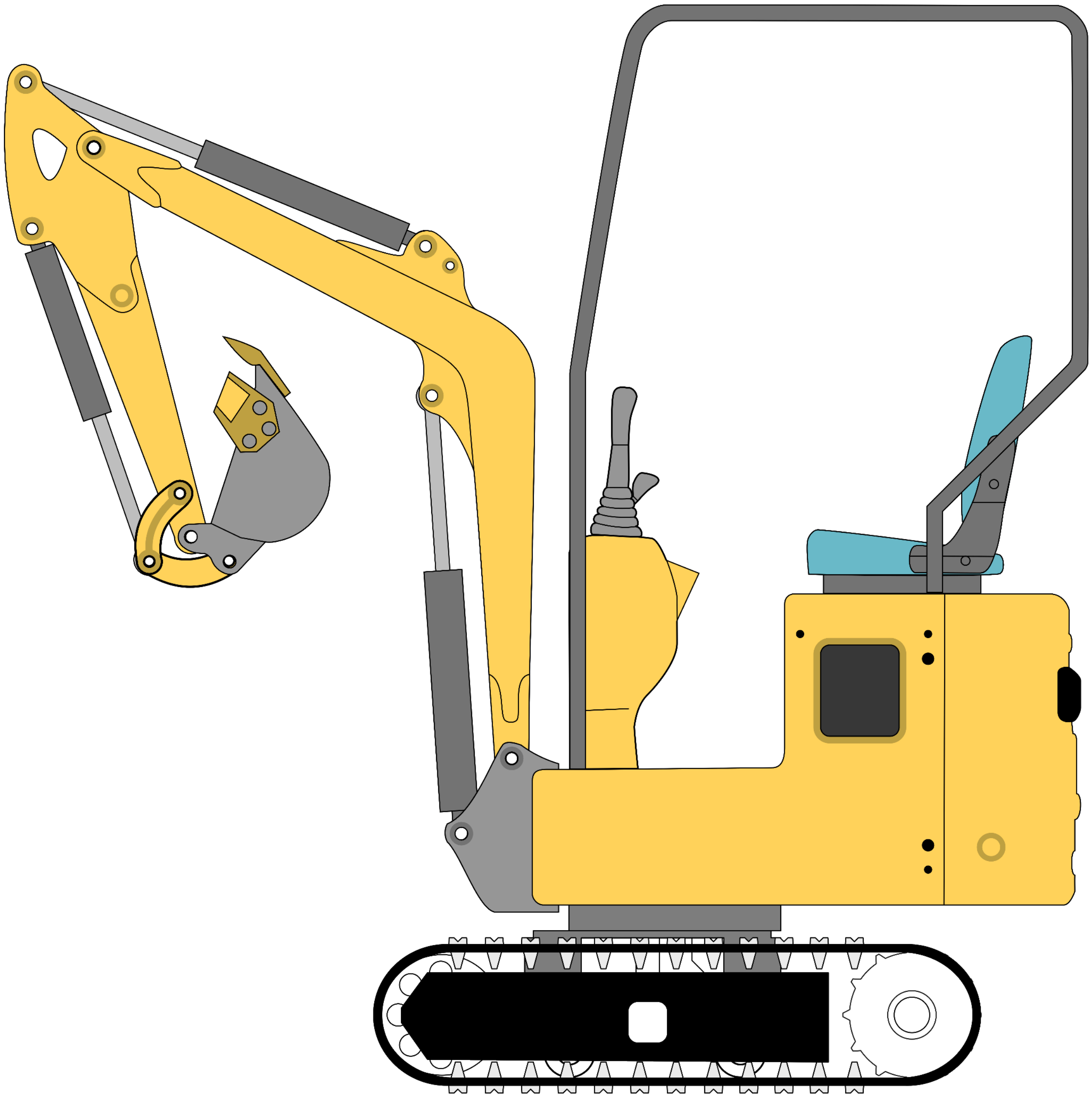
To ensure a bucket or tool fits your machine we need to check a couple of dimensions. Below is a brief explanation of the main measurements used to determine if a tool fits. There are other considerations that we will discuss later.

A bucket or tool attachment is secured with two pins. In some machines the pin is a large 25mm by at least 160 mm screw secured in the other end with a nut. Better machines will have “L” shaped pins where the pin is secured by screwing a cap. These pins are stronger and make changing tools easier.

<table>
<tr><td>A is the diameter of the pin hole that attaches the tool to the arm/stick. Pins on micro excavators are usually 25 mm of diameter.</td><td rowspan="3">
</td></tr>
<tr><td>B is the diameter of the pin hole that attaches the tool to the actuator cylinder. Pins on micro excavators are usually 25 mm of diameter.</td></tr>
<tr><td>C is the distance from the center of the holes. (Distance between centers). To make measurement easier, measure from the front edge of one pin to the front edge of the second hole. The common distance found in buckets and attachments is 90 mm.</td></tr>
<tr><td>D is the inside distance from ear to ear of the arm/stick pin. (also known as gap, the span of the stick) The common distance is 92 mm, but this will vary.

To ensure compatibility, compare this measurement with the width of your arm/stick.</td><td rowspan="2">
</td></tr>
<tr><td>E is the inside distance from ear to ear of the actuator cylinder. (also known as dipper gap, or the span of the dipper)

The common distance is 92 mm, but this will vary. To ensure compatibility, compare this measurement with the width of your H-Link or your quick-hitch.</td></tr>
</table>



Operation and Limits

Safety and Regulations

`Disclaimer:` Digging the regulatory framework of these tiny excavators prove to be an interesting challenge, with a lot of things left unanswered. To be responsible we are working to send some formal inquiries to OSHA's Office of Standard Interpretations and we will update this document as we get more information.

We don't need to stress that safety is fundamentally about saving lives; we're not going to focus on common sense and safety basics here. You already know that even if something isn't explicitly mentioned in an OSHA regulation, Section 5(a)(1) of the Occupational Safety and Health Act allows OSHA to cite you for a safety violation. This section will primarily address the specific safety requirements and regulations applicable to the machine itself.

While in Canada and Europe these mini excavators are excluded from many safety requirements and regulations due to their weight in the US is far more complicated than that. So let's start with the EU and Canada to cover the easy stuff.

To sell these machines in Europe the mini excavator MUST earn the "CE" sticker by getting their machines certified (ISO 12100 and others). The requirements of ISO 12100 are mainly about operational safety. If you live in an EU country do not buy a machine unless you get proof of CE certification. In the EU and Canada machines with a mass of 800 kg or less are excluded from many regulations (see ROPS/TOPS for an example).

In the US we need to understand the context of its use. OSHA regulations apply as soon as the word "employee" can be applied. You are off the hook from OSHA for personal/residential work on your own, but be careful with contracted/paid work. In general OSHA is about ensuring the safety and health of workers, you as an owner may actually be considered an employee in many circumstances. You also have to consider requirements from the company or entity that hires you as they may impose OSHA inspections on your operation.

For regulations a mini excavator is not an agricultural/industrial tractor nor is it a crawler tractor, or a loader. The mini excavator meets the formal definition of an excavator which puts them in a weird place in particular with 29 CFR 1926.602 and similar regulations. Many of the safety requirements of an excavator are dictated by the Power Crane and Shovel Association (PCSA) standard No. 5 "Mobile Hydraulic Excavator Standards". Along with the PCSA, states can also add additional requirements.

OSHA's 29 CFR 1926.602 is one of the common sections we see in construction, yet 1926.602 does not apply to track mounted excavators with rotating housings. Instead we have other regulations that apply by context, for example 29 CFR 1926.604 establish protections for employees engaged in site clearing and thus your machine used in this manner will be required to have some covering and woven wire mesh protection.

Publication 2004-107: [Preventing Injuries When Working with Hydraulic Excavators and Backhoe Loaders]

A lot of things that you may complain about a small 1 ton machine are simple decisions made by manufacturers to stay within the lowest regulatory umbrella possible. Notice that this does not necessarily mean that they are playing around the rules, the form factor at this price point does limit these machines.

ROPS, TOPS, FOPS Requirements

Let's start by making some distinctions, a rollover implies a full rotation on an axis, that is you roll to the sides a full circle and a tip over is the milder version where you only fall flat 90° on a hard soil surface and stop. Then we have the risk of falling objects which generally means debris and projectiles falling vertically and front/back protection.

A Rollover Operator Protective Structure (ROPS) is a structure designed to protect an operator during a machine rollover, that means that it can withstand lateral forces and deflection as defined by a standard relative to the machine mass and expected operating forces. A Tip over Operator Protective Structure (TOPS) is very similar to ROPS but meant for lesser forces. A Falling Object Protective Structure (FOPS) is the particular protection provided against large debris and objects falling on the machine.

Just because a machine has a cage structure, bars or cabin that does not mean it has ROPS/TOPS/FOPS. The terms ROPS/TOPS/FOPS are actually the name of legal requirements that machinery must meet to operate under certain scenarios and conditions. Each country defines their requirements but they all tend to align with ISO 12117, ISO 12117-2, ISO 3471. Legally a protective structure is not ROPS/TOPS/FOPS unless it's certified by an independent testing entity and bears a certification label attesting conformity.

In the EU these small machines are explicitly excluded from ROPS requirements in EN 474-5:2022. In the same line in the EU excavators with an operating mass greater than 1 ton and less than or equal to 6 ton according to ISO 6016:2008 are required to have TOPS. We have not done much research for Canada but a quick search on Google seems to indicate that similar to the EU there is a base weight of 800 kg or about 1763 lbs and these machines are well below that. Remember that generally a chinese excavator marketed at 1 ton will weigh far less than a ton.

In the US ROPS/FOPS requirements are defined by 29 CFR 1926.602, 29 CFR 1926.1000 and 1926.1001. Notice that none of these apply to a mini excavator.

Regardless of actual laws, mini excavators sit in a weird place compliance wise. For excavators of less than 6-tons we generally do not talk about ROPS because the ROPS testing standards do not cover these machines. TOPS can be used for 1 ton machines, but this “1 ton” is the actual real mass, most mini excavators are not 1 ton. Mini excavators of 1 ton of less are in a sort of limbo. OSHA can require ROPS and TOPS but ISO 3449 simply does NOT have any testing criteria for such a small machine. Some of the advisory committees meetings at OSHA may suggest that OSHA is looking at mini-excavators and it seems that there is an inclination for TOPS to become a requirement for mini-excavators in the US.

One issue we have is that only the big brands are participating in these committees, and those machines are not quite comparable to the Chinese excavators we cover in this guide. For example the smallest mini from CAT weights 2061 lbs and a John Deer is a whopping 7000 lbs. I guess it is time to start using the term micro-excavator to make a distinction.

When it comes to ROPS/TOPS the only real conversation is whether the machine has adequate operator protection.

Slopes

Is common to see 1 ton mini excavators indicating that they can handle 30° of incline. This number may get you in a lot of trouble. If you look closely you will notice that for RIPPA and AGT the documentation actually reads 30% of Climbing Ability, notice that is 30% percent and not degrees.

Gradeability or climbing ability is the steepest slope a machine can drive on and operating angle is the angle a machine can operate without moving.

Gradeability is a percentage of 45 degrees, where 45° is the established max for these types of machines. The formula to compute the degree for a percentage is tan-1(slope percent/100). A mini excavator with 30% of Climbing Ability can handle slopes of 16.7° degrees or 17°.

If your machine has a CE certification you can ask the vendor for the Certification Reports. In the reports you will find all the specifications including gradeability.

This number is not so arbitrary, manufacturers have to consider cavitation of fluids like hydraulic oil, engine specifications and the ability to brake. For example the Briggs & Stratton oil sump is only rated for 15°. There are also ISO standards that set the safe limits for being able to stop a machine on a slope. Given that these machines have no additional brakes the gradeability has to be compensated to allow them to stop the machine mass within the safe limits.

The lateral tilt angles of these machines are very unforgiven. Traveling parallel to a slope or overcoming a lateral obstacle that tilts the machine in excess of 10° degrees will cause the machine to roll on the side.

Remember when traveling perpendicular to the slope these machines are actually certified for 17° and no more than 20° of incline. The load and the position of the boom will actually determine what you can get away with safely.

When facing a slope we extend the boom, keep the load close to ground to offset our center of gravity and travel slowly. How far we extend the boom will change the tipping point and balance of the machine. Balancing your center of gravity is important to reduce wear of your swing assembly and motor. Never travel on a slope with the bucket too high/far or to the sides. The more your boom is rotated laterally or lifted the more susceptible the machine is to roll even on flat surfaces. The bucket close to the ground will help in case of emergencies, it may stop the machine from tipping, it can be used as a brake or to stabilize a bouncing machine.

There are two camps when it comes to how you drive up/down hill. There is a group that always drives with the blade forward to use it in case of emergencies and for stability and the other camp is to keep the sprockets (motors) downhill (the dozer blade in the back of the travel direction). The main argument of the sprockets downhill is to keep the bottom of the track tensioned, reducing the possibility of derailment. How you feel about one or the other is up to you.

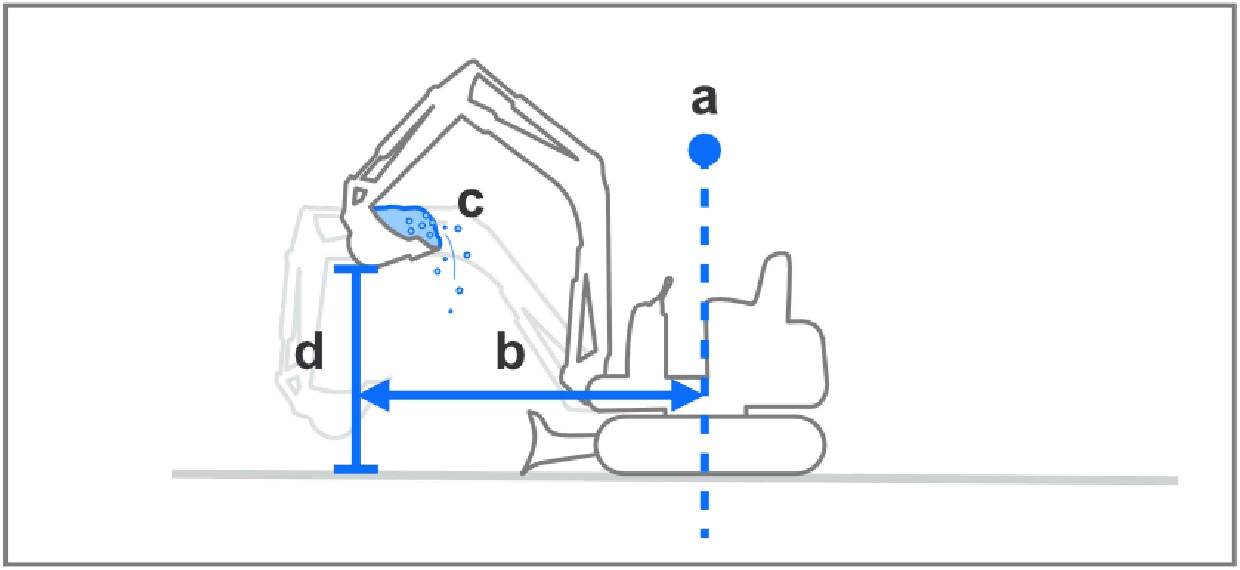
When you transition from flat to a slope these machines bounce and that's when you are at most risk of tipping. You can use your bucket on the ground to control the transition.

The small hydraulic oil tanks used in these excavators can expose the tank inlet to air when traveling in an incline. This will cause air to flow in your system or simply interrupt the flow of oil. When this happens air that enters the system increases the chances of cavitation which in turns can damage your pump and other components.

Lifting and Hoisting

The traditional 1 ton machine is designed explicitly to be able to handle a bucket load (bucket/shovel operation) from a given depth to a given height with the bucket extended at a given distance. Officially these machines are not designed for hoisting, where hoisting is lifting of freely suspended loads (ie lifting and moving pipes, trees, unloading construction materials, etc).

The lifting capacity for bucket operation is defined by ISO 10567. A 1 ton machine sold in the EU must have a rated bucket lifting capacity, sadly the lifting capacity of these machines is seldomly published.



The “rated capacity” (Safe Working Load) is the weight of load (c) that can be handled at the maximum allowed distance of the load point (b). This rated capacity will also give you the maximum height (d) of the lift point (not the load). This rated capacity is actually a balanced ratio around the machine center of gravity (a), will talk more about that later.

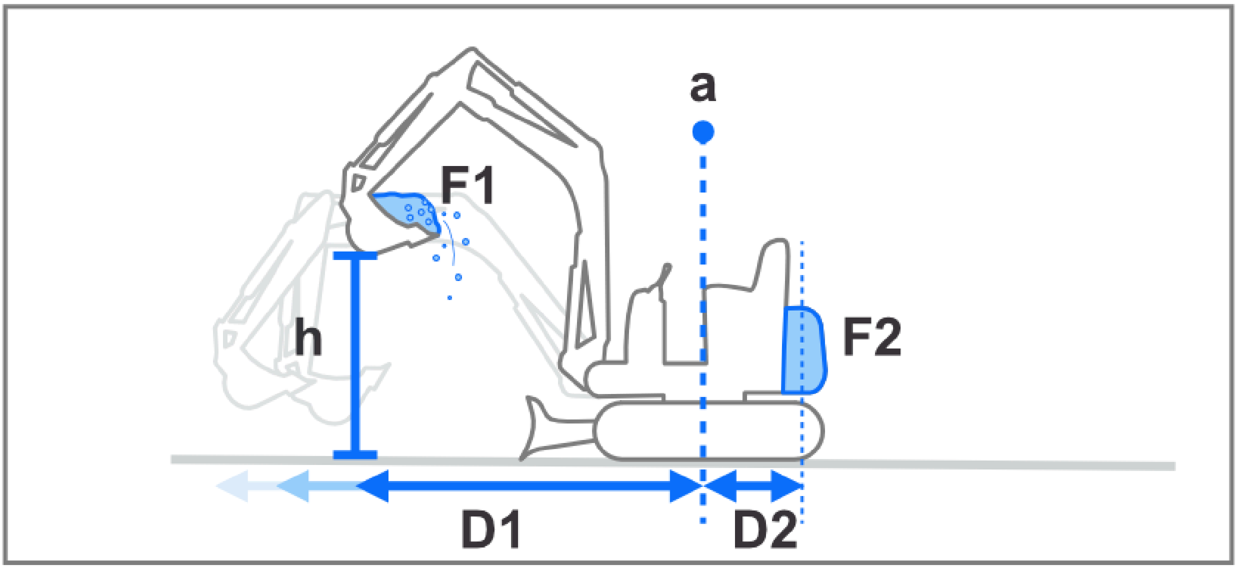
The formulas are:

Lift Height = (Load Kg x Distance of Bucket) / Counter Mass
Load Kg = (Lift Height * Counter Mass) / Distance of Bucket
Distance of Bucket = (Lift Height * Counter Mass) / Load Kg

The manufacturer must be able to provide you with the following information: a chart of Lift capacity ratings (load point heights (d) in relation to load radius/distance (b)), and a list of parameters for their calculation of stability. The lift chart may be affixed to your machine as a sticker. That is the formal information that you need to operate your machine safely.

With that said we know that's not the reality so this section will attempt to give you some insights on load capacity and lifting. We need to clarify that load calculations have to account for far more variables and conditions, like terrain, machine stance, slopes, and hydraulic limits that we will not go into details here, so use this information only as a base and educate yourself more!

We modified the previous figure to show you the basics of equilibrium at play.



Your machine is at balance when this equation is true (D1 x F1) = (D2 x F2). Here F1 is the weight of the load we lift, F2 is the weight of the machine's counterweight or structural weight. D1 is distance to the load point F1 from the gravity center (a) (by design the swing center) in a mini excavator; this point may be the boom pivot point when the machine itself acts as the counter mass. D2 is the distance from the gravity center to the center of the counter mass, if the whole machine acts as a counter mass is the width of the upper carriage. If you look at it is just all about balancing a seesaw but the distances are not equal.

Another way to see this formula is as a ratio. If we make the weight of F1 and F2 the same then the only factor left is the distances. If D1 is four times the distance of D2, then you can simplify things and say that the counterweight for a given weight (F1) is four times the weight of F1. Here D1 is the longest distance we expect in the range of motion to be performed while we lift. The ratio is simply D1 divided by D2. If D2 is 2 feet and D1 is 8 feet then the ratio is 8/2=4 or 4 to 1. So to lift 50 lbs (while keeping the bucket 8 feet from center) will take a counterweight of 200 lbs. Remember that all mini excavators have a structural counter mass even if no physical counterweights are installed. (Please don't use these numbers as reference, I just picked numbers that my brain can do math with!)

Notice that as we move the bucket in the range of travel the distance D1 will change, the machine becomes more unbalanced the farther the load is. The reach of your bucket will dictate how high and what loads you can lift. As you extend the distance of the bucket two things must happen to keep the machine from tipping, you either reduce the height or reduce the load. To maximize your lifting you need to keep that bucket close to the machine.

The tipping point of an excavator occurs when the weight of the bucket (F1) becomes the new center of gravity (tipping load). Your machine is now balancing about the load. That's where counterweights play a role in your lift capacity. If you plan to do lifting or handle loads beyond the factory design you need to at minimum add prover counterweights (F2) to match the expected loads while maintaining proper ratios. We included the formulas above but there are plenty of better resources online explaining proper use of counterweights and balance ratios.

Here are some pointers on modifying your machine to add counterweights:

> Before you consider adding counterweights because your machine feels tippy, consider taking more time to get more comfortable balancing the load by adjusting the placement of the bucket relative to the machine's center of gravity. This is something that as you get more proficient you should be able to make adjustments as you travel almost without even thinking about it.
>
> Counterweights mods should be removable and adjustable. Your machine was designed at the factory to be balanced at the center of the swing assembly, permanent counterweights will unbalance the machine when the bucket load is below its balance ratio, this will damage your swing assembly and motor. Unless you expect to work with fairly similar loads, having a fixed counterweight will not help much and probably will add more wear to your swing assembly.
>
> In addition to making counterweights adjustables you may go back to the formula and see that the balance is not only counterweight but distance. In our original examples of a 4 to 1 ratio, if we double the placement distance of the counterweight we will reduce the required weight of the counterweight by half. Consider a setup where you can adjust the distance of the counterweight.

When hoisting things (lifting of freely suspended loads) things get more complicated. In general freely suspended loads should be kept below 75% of the bucket load capacity.

There are some additional things that you need to keep in mind. A machine designed for lifting will have load holding valves to ensure hydraulic oil levels at the cylinder do not drain out while lifting among other valves to ensure safety that most mini do not have. Constant excessive hydraulic forces can create failures in hoses, add additional wear on seals and reduce the practical life of many components. Finally the one everybody ignores, these machines do not have the stance to do any lifting on their side. Be extra careful when rotating loads sideways and take your time to learn your machine's limits.

Warranties

Warranties like always are extremely bogus. Here we can only speculate a bit and limit ourselves to our experience.

Warranties are commonly limited to drive components (hydraulic motors and pumps). Motors and pumps are quite simple and take a lot of abuse, so chances are that something else will break before a hydraulic motor or the pump needs replacement. Abuse, bad maintenance, etc will likely kill seals and o-rings which would not be covered on the warranty. Hoses, seals, o-rings, bucket/boom/arm pins and many others are all considered consumables.

Pretty much engines don't have warranties. Explain why…

The warranty period is in hours with some time limit like a year, whichever comes first. So when you hear about a "3 year" warranty there is most likely an hour limit to the warranty period, just like with cars.

We haven't had to do any claims yet (knock on wood), but in the case of RIPPA, they gave us 150 hours/1yr on drive components. We contact them and settle which part needs to be replaced (very vague on the process) and they will ship a replacement hydraulic motor, etc from China free of cost and we are responsible for the repair and labor.

APPENDIX: ISO 228 / BSP Parallel Threads

ISO 228 is intended for threads with elastomeric or metal-to-metal sealing.

ISO 228 is BSPP (parallel)
ISO 7-1 is BSPT (taper thread)
ISO 228 is equivalent to DIN ISO 228-1 and JIS B0202.

G Size (in)	Major (Outside) Diameter (mm)	Minor (Nut) Diameter (mm)	Core Hole Diameter (mm)	Thread Count (TPI)	Thread Pitch (mm)
G 1/4	13.16	11.89	11.80	19	1.337
G 3/8	16.66	15.39	15.25	19	1.337
G 1/2	20.95	19.17	19.00	14	1.814
G 5/8	22.91	21.13	21.00	14	1.814
G 3/4	26.44	24.66	24.50	14	1.814
G 7/8	30.20	28.42	28.25	14	1.814
G 1	33.25	30.93	30.75	11	2.309
G 1 1/8	37.90	35.58	35.30	11	2.309
G 1 1/4	41.91	39.59	39.25	11	2.309
G 1 3/8	44.32	42.00	41.70	11	2.309
G 1 1/2	47.80	45.48	45.25	11	2.309
G 1 3/4	53.74	51.43	51.10	11	2.309
G 2	59.61	57.29	57.00	11	2.309

G 2 1/4	65.71	63.39	63.10	11	2.309
G 2 1/2	75.18	72.86	72.60	11	2.309
G 2 3/4	81.53	79.21	78.90	11	2.309
G 3	87.88	85.56	85.30	11	2.309
G 3 1/4	93.98	91.66	91.50	11	2.309
G 3 1/2	100.33	98.01	97.70	11	2.309
G 3 3/4	106.68	104.30	104.00	11	2.309
G 4	113.03	110.71	110.40	11	2.309

APPENDIX: ANSI/ASME B1.20.1, SAE AS71051, US National Pipe Tapered Threads

ANSI/ASME B1.20.1 is NPT Tapered Thread (Taper = 1° 47’)
Angle: 60° flank/thread angle

A pipe thread sealant is always required when mating up tapered threads.

Standards are: ANSI/ASME B1.20.1, SAE AS71051

Nomenclature				
1-1/4	**-**	**12**	**UNF**	**2B**
Nominal Diameter (IN)		Pitch in TPI	UN UNF	Class 1A, 2A, 3A, 1B, 2B or 3B.

"B" Internal thread, "A" external.
UNC = Unified Coarse, UNF = Unified Fine

Nominal Diameter	Major Diameter Inch	Major Diameter mm	Tapping Drill Size mm	TPI	Pitch mm
#0 - 80 UNF	0.0600	1.524	1.25	80	0.317
#1 - 72 UNF	0.0730	1.854	1.55	72	0.353
#2 - 64 UNF	0.0860	2.184	1.90	64	0.397
#3 - 56 UNF	0.0990	2.515	2.15	56	0.453
#4 - 48 UNF	0.1120	2.845	2.40	48	0.529
#5 - 44 UNF	0.1250	3.175	2.70	44	0.577
#6 - 40 UNF	0.1380	3.505	2.95	40	0.635
#8 - 36 UNF	0.1640	4.166	3.50	36	0.705

#10 - 32 UNF	0.1900	4.826	4.10	32	0.794
#12 - 28 UNF	0.2160	5.486	4.70	28	0.907
1/4" - 28 UNF	0.2500	6.350	5.50	28	0.907
5/16" - 24 UNF	0.3125	7.938	6.90	24	1.058
3/8" - 24 UNF	0.3750	9.525	8.50	24	1.058
7/16" - 20 UNF	0.4375	11.112	9.90	20	1.270
1/2" - 20 UNF	0.5000	12.700	11.50	20	1.270
9/16" - 18 UNF	0.5625	14.288	12.90	18	1.411
5/8" - 18 UNF	0.6250	15.875	14.50	18	1.411
3/4" - 16 UNF	0.7500	19.050	17.50	16	1.587
7/8" - 14 UNF	0.8750	22.225	20.40	14	1.814
1" - 12 UNF	1.0000	25.400	23.25	12	2.117
1-1/8" - 12 UNF	1.1250	28.575	26.50	12	2.117
1-1/4" - 12 UNF	1.2500	31.750	29.50	12	2.117
1-3/8" - 12 UNF	1.3750	34.925	32.75	12	2.117
1-1/2" - 12 UNF	1.5000	38.100	36.00	12	2.117

Nominal Diameter	Major Diameter Inch	Major Diameter mm	Tapping Drill Size mm	TPI	Pitch mm
#1 - 64 UNC	0.073	1.854	1.50	64	0.397
#2 - 56 UNC	0.086	2.184	1.78	56	0.453
#3 - 48 UNC	0.099	2.515	2.05	48	0.529
#4 - 40 UNC	0.112	2.845	2.27	40	0.635
#5 - 40 UNC	0.125	3.175	2.59	40	0.635
#6 - 32 UNC	0.138	3.505	2.77	32	0.794
#8 - 32 UNC	0.164	4.166	3.42	32	0.794

#10 - 24 UNC	0.190	4.826	3.82	24	1.058
#12 - 24 UNC	0.216	5.486	4.47	24	1.058
1/4" - 20 UNC	0.250	6.350	5.11	20	1.270
5/16" - 18 UNC	0.313	7.938	6.55	18	1.411
3/8" - 16 UNC	0.375	9.525	7.95	16	1.587
7/16" - 14 UNC	0.438	11.112	9.30	14	1.814
1/2" - 13 UNC	0.500	12.700	10.73	13	1.954
9/16" - 12 UNC	0.563	14.288	12.15	12	2.117
5/8" - 11 UNC	0.625	15.875	13.53	11	2.309
3/4" - 10 UNC	0.750	19.050	16.46	10	2.540
7/8" - 9 UNC	0.875	22.225	19.34	9	2.822
1" - 8 UNC	1.000	25.400	22.15	8	3.175
1 1/8" - 7 UNC	1.125	28.575	24.87	7	3.628
1 1/4" - 7 UNC	1.250	31.750	28.05	7	3.628
1 3/8" - 6 UNC	1.375	34.925	30.60	6	4.233
1 1/2" - 6 UNC	1.500	38.100	33.70	6	4.233
1 3/4" - 5 UNC	1.750	44.450	39.26	5	5.080
2" - 4 1/2 UNC	2.000	50.800	45.03	4.5	5.644
2 1/4" - 4 1/2 UNC	2.250	57.150	51.38	4.5	5.644
2 1/2" - 4 UNC	2.500	63.500	57.00	4	6.350
2 3/4" - 4 UNC	2.750	69.850	63.36	4	6.350
3" - 4 UNC	3.000	76.200	69.71	4	6.350
3 1/4" - 4 UNC	3.250	82.550	76.06	4	6.350
3 1/2" - 4 UNC	3.500	88.900	82.41	4	6.350
3 3/4" - 4 UNC	3.750	95.250	88.76	4	6.350
4" - 4 UNC	4.000	101.600	95.11	4	6.350

Reference website.