BUILD YOUR OWN

OFF-ROAD BUGGY

FOR AS LITTLE AS £100

RON CHAMPION

First published in March 2002
Reprinted September 2002
Reprinted 2004 (twice)

A catalogue record for this book is available from the British Library.

ISBN 1 85960 642 3

Library of Congress catalog card no. 2001132567

Published by Haynes Publishing, Sparkford, Yeovil,
Somerset BA22 7JJ, UK
Tel: 01963 442030 Fax: 01963 440001
Int. tel: +44 1963 442030 Fax: +44 1963 440001
E-mail: sales@haynes.co.uk
Website: www.haynes.co.uk

Haynes North America Inc., 861 Lawrence Drive,
Newbury Park, California 91320, USA

Printed and bound in Britain by J.H. Haynes & Co. Ltd, Sparkford

WARNING
While every care has been made throughout this book to emphasise the safety aspects of building your own Buggy, the publishers, the author and the distributors accept to liability whatsoever for any damage, injury or loss resulting from the use of this book. If you have any doubts about your ability to safely build your own Buggy then it is recommended that you seek advice from a professional engineer.

Contents

Dedication

This book is dedicated to the memory of my mother, Ann Elizabeth Champion, who passed away in the Autumn of 2000. Having seen the early photographs of the Buggy she unfortunately did not live to see the project completed, nor to have the opportunity to have a go, which, even at the age of 77, I am sure she would have done. The spirit of adventure and enthusiasm is in the soul and should not be discouraged. I hope that having read this book, like my old Mum, it inspires you to have a go.

Acknowledgements

I would like to acknowledge the assistance of those who have helped to make this book a reality.

First and foremost I would like to thank Rory Perrett for his contribution, especially in the preparation of the manuscript and the drawings used in the book, and without whom it might never have been completed.

I would also like to thank Steve Williams for the taking the photographs, and Gordon Gilbert for producing the original 3D CAD drawing of the Buggy's frame. Thanks also to John Hardaker who produced the line drawings in their finished form, and to front cover model Karen Thurston.

I would like to thank Justin Cole of Racers Hardware, Crowland for his technical expertise, the use of facilities and the support from all his staff, especially Colin and Trudi, and a big thank-you to Derek Manders for trying out my manuscript to see if you really could build a Buggy from it.

Finally, I would like to thank my wife, Mary, for supporting me in the writing of another book.

BUILD YOUR OWN

OFF-ROAD BUGGY

FOR AS LITTLE AS £100

Introduction

When you're the son of a car-mad engineer you really don't stand a chance! James, who like me grew up surrounded by cars, parts of cars, tools, oil, etc, was one of those sons. Now, twenty or so years on, he's a driver in the successful Locost car race series for cars built to the design appearing in the book I wrote in 1996. The first Locost car was built for James, and since the book *Build Your Own Sports Car For As Little As £250* was published, thousands of other people have been able to enjoy building their own car. However, the Locost wasn't the first vehicle to be built for James!

James always liked going with me to the local dump, an event that usually resulted in us returning with more than we took. On one occasion, when he was about four years old, we found a small commercially built go-kart, which had a steel chassis, 1½in-wide pump-up tyres on wire wheels, and was propelled, like a bicycle, with pedals connected by a chain to the back axle. The kart was missing only the seat and the steering wheel, and the rest of the weekend was spent getting this contraption into working order. Another trip to the dump secured a plastic seat from a stacking chair, and a steering wheel was found and secured to the steering column. For the next few weeks James had a great time peddling his 'car' round and round the garden, until he decided that the effort of peddling was too much like hard work.

As I'm the type of person who never throws anything away – the trips to the dump were always to dispose of my wife's junk – I had a search in the shed and the garage to see what I could come up with to motorise the kart. It was decided that the starter motor from a Mini car would provide power, and that the manually operated starter solenoid switch from a Morris Minor would be the 'go' switch. A Suffolk Colt lawnmower gave up its smallest 8-toothed sprocket, which was brazed to the shaft of the starter motor once the Bendix gear mechanism had been removed. A few cables, an old car

The author gives two new drivers tips on how to handle the prototype Buggy. (Steve Williams)

battery and a couple of hours work later, James was the proud owner of his own self-propelled vehicle. We did have one or two teething problems; I prefer to call it 'R and D'! The power delivery to the back wheels was instantaneous, with James's head being jerked violently backwards every time he pressed the 'go' switch, and lots of wheelspin due to the tyres having to act as a clutch. Great fun for James, but of great concern to his mother, not only because of the grooves appearing across the lawn, but also because of the damage it could be doing to her precious son's brain as his head was thrown around. On the technical front, the biggest problem was that the kart wouldn't steer. The solid axle driving the two rear wheels wanted to propel the vehicle forwards in a straight line, regardless of whether the front wheels were pointing to the left or to the right.

The following weekend I was back out in the workshop salvaging some more sprockets from the Suffolk Colt. Using the new sprockets, together with some lengths of chain, we built a reduction gearbox. This not only reduced the torque and lowered the top speed, but also virtually eliminated the wheelspin, making the whole vehicle a lot more usable. An additional bonus was that because the kart now had several chain runs there was a delay between the solenoid being operated and the drive fully taking up the slack in the chains, which in turn saved the strain on James's neck. We solved the steering problem by having only one of the rear wheels on the rear axle driven, leaving the other free to rotate, creating a sort of crude differential.

Braking was provided by a hand-brake that operated directly on the rear tyres, but we were also pleased to find that as soon as the power was switched off the motor became a very effective brake. I did have thoughts of regenerative braking using complicated switchgear to recharge the battery!

James used the kart regularly for the next few years until he got his first motorcycle at the age of seven. The electric kart was passed onto a French family and is still being used by the next generation of youngsters.

After playing around with the kart, I got into motorcycle-engined buggies when I was involved in youth and community work, and came up with a basic design not dissimilar to the one in this book. Young people in a youth training workshop who recycled the major components from scrap motorcycles successfully built dozens of these buggies.

After building the prototype Buggy which appears in this book, and having written the first draft of this book, I decided that it would be a good idea to see if it was, in fact, possible for someone to build a Buggy using my instructions! A willing volunteer was found in the shape of Derek Manders, an old friend who had successfully built a

The prototype Buggy in action. (Steve Williams)

Derek Manders's granddaughter, Charlotte, at the wheel of his Buggy. (Derek Manders)

Locost using my first book, *Build Your Own Sports Car For As Little As £250.* Having heard about the Buggy project, Derek decided that he would like to build one for his granddaughter, Charlotte. So, armed with a copy of the original manuscript for this book, some photographs of the building of the prototype Buggy, and a complete welded Buggy frame, we sent him off to see what he could do. Derek's brief was to incorporate his own ideas and build his own variation on the Buggy concept, on the understanding that as long as he didn't alter the frame from the standard one supplied, the rest was up to him. You'll find that I have included some of Derek's alternative solutions to the Buggy build as 'Alternative solutions' sidebars in this book, just to reinforce the message that I've described one way to build a Buggy, but it's not the only way. The book shows the basic design and is intended to get you started and to get you thinking. Skilled engineers might wish to modify the design, but my advice is to stay small and simple. If the design is varied, seek the advice of a competent engineer or someone experienced with off-road vehicles. The original design is thoroughly tried and tested.

Chapter 1

Skills required

I've found that enthusiasm breeds skills, and during my many years as an engineering instructor I've seen time and again that if someone really wants to do something, they find that, with application, they *can* do it. Since you've bought this book, though, I assume it's more likely than not that you already have some basic mechanical skill and knowledge. If this isn't the case, all is not lost, as there are several ways (formally and informally) to acquire the skills you will need.

First and foremost, in building your Buggy on a minimal budget, the most important skill you're going to need is patience, as it will take time to source the materials and parts, and build everything yourself. Patience is also an essential aspect of learning to weld.

WELDING

The most important equipment for joining metal is a welder, and the most important skill is knowing how to use it. This is a skill you can teach yourself from instruction books and by practising on metal scrap, though most will benefit from professional tuition. Equipment suppliers are generally prepared to give basic instruction to new purchasers of welding equipment.

There are also several training centres specialising in welding, and most technical colleges and further education institutes offer evening classes in all types of welding and metal fabrication.

Booklets containing useful information on equipment and safety procedures can be obtained from the British Oxygen Company (BOC) Group, and that company also produces a range of training videos. (Contact BOC Gases, The Priestley Centre, 10 Priestley Road, Surrey Research Park, Guildford, Surrey GU2 5XY. Phone: 01483 579857.)

When buying second-hand, be sure that the vendor gives you a satisfactory demonstration of the equipment in use. He may also be prepared to give you some basic instruction as well.

Even if you already have experience of welding, it's essential to familiarise yourself with the equipment and materials you will be using. I've been welding for over 30 years, but when using an unfamiliar welding set I always try a test weld on a piece of scrap, preferably an offcut from the material I am about to use. It would be a good idea to make up a rectangle or a cube from the tube you will be using to make the frame of your Buggy, and keep practising until your joints are perfect.

Welding equipment available to the home builder is likely to be one of 3 main types, gas (oxy-acetylene), MIG (metal inert gas) and arc.

Metal cleaning

Whatever type of welding you use, the pieces of metal to be welded must be free from rust and clean. The cleaner the metal, the better the joint. Good wire brushes, emery cloth and wire wool will help you clean up your joints both before and after welding.

Gas welding

This is traditional oxy-acetylene welding, a method developed by the French at the beginning of the century using the two gases oxygen and acetylene. The advantage is that this method does not need a supply of electricity, so it can be used anywhere. The main supplier of oxy-acetylene equipment in the UK is the BOC Group, and while you can purchase torches, hoses and gauges, the gas cylinders can only be rented. Ideal for small jobs is the BOC Portapak.

It's vitally important to follow the correct safety procedures when using pressurised cylinders, and for new users this needs to become a habit from the beginning. Gas cylinders are colour coded – acetylene cylinders are maroon and oxygen cylinders are black. Acetylene smells of garlic and burns with a smoky yellow-orange flame, but when correctly mixed with oxygen an incredibly hot flame is produced.

Make sure the equipment you are using is fitted with flashback arresters to prevent flames travelling back into the cylinders. Pressure regulators are screwed into the cylinder valves – in the case of acetylene cylinders a left-hand thread is used, and for oxygen cylinders it's a right-hand thread. The hoses connecting the pressure regulators to the torch are red for acetylene and blue for oxygen. Check that the hoses are of best quality and in good condition (do not use them if there are signs of wear), and have hose check valves fitted.

Always keep gas welding equipment free from oil and grease, follow the supplier's instructions when assembling and, when assembled, check for leaks. I use a cup of soapy water and a paint brush to brush water over the joints. If there are any leaks, they will show as bubbles. If you do detect a leak it can quite often be cured by a further 'nip' with a spanner, but if this doesn't work and you are quite sure all the threads were clean, do not tamper with it – take the cylinder back to the supplier and have it checked. Do not over tighten any of the joints as most of the fittings are made of brass and the threads are easy to strip.

Before you get started be sure that your work area is free from any combustible material, such as oily rags, fuel tanks etc, and that it is well ventilated. See also that your cylinders are secured in an upright position (preferably chained on a trolley), and wear the correct welding goggles and gloves. Having familiarised yourself with the operating instructions and set the gas pressures for the steel thickness you are going to work on (all shown in the BOC booklet), open the acetylene valve and light your torch with the spark igniter. Adjust the acetylene flame until the smoke just disappears, then open the oxygen valve until you achieve a clearly defined very light blue central flame. This central flame will be surrounded by a darker blue outer flame which shows you are using equal amounts of both gases. This is known as a neutral flame – ideal for welding steel.

If you're right-handed, hold the welding rod in your left hand and start on the right-hand side of the joint to be welded. If you're left-handed, hold the welding rod in your right hand and start on the left side of the joint. Bring the flame to a little over 1/8in from the joint, and hold the nozzle at about 70 degrees. Through your goggles you will see the steel turn into a molten pool. The welding rod tip is introduced into the molten steel where it will also melt and mix. You then move the flame along the joint, allowing the molten pool and welding rod to mix as you go.

Fig. 1.1. Gas welding equipment. The taller cylinder contains oxygen, the shorter one acetylene. Suitable protective clothing, dark goggles or a mask and thick gloves should be worn when welding. (Steve Williams)

Although it will take some time to fully master the art of oxy-acetylene welding your frame, once you have done so it is a satisfying though slow process.

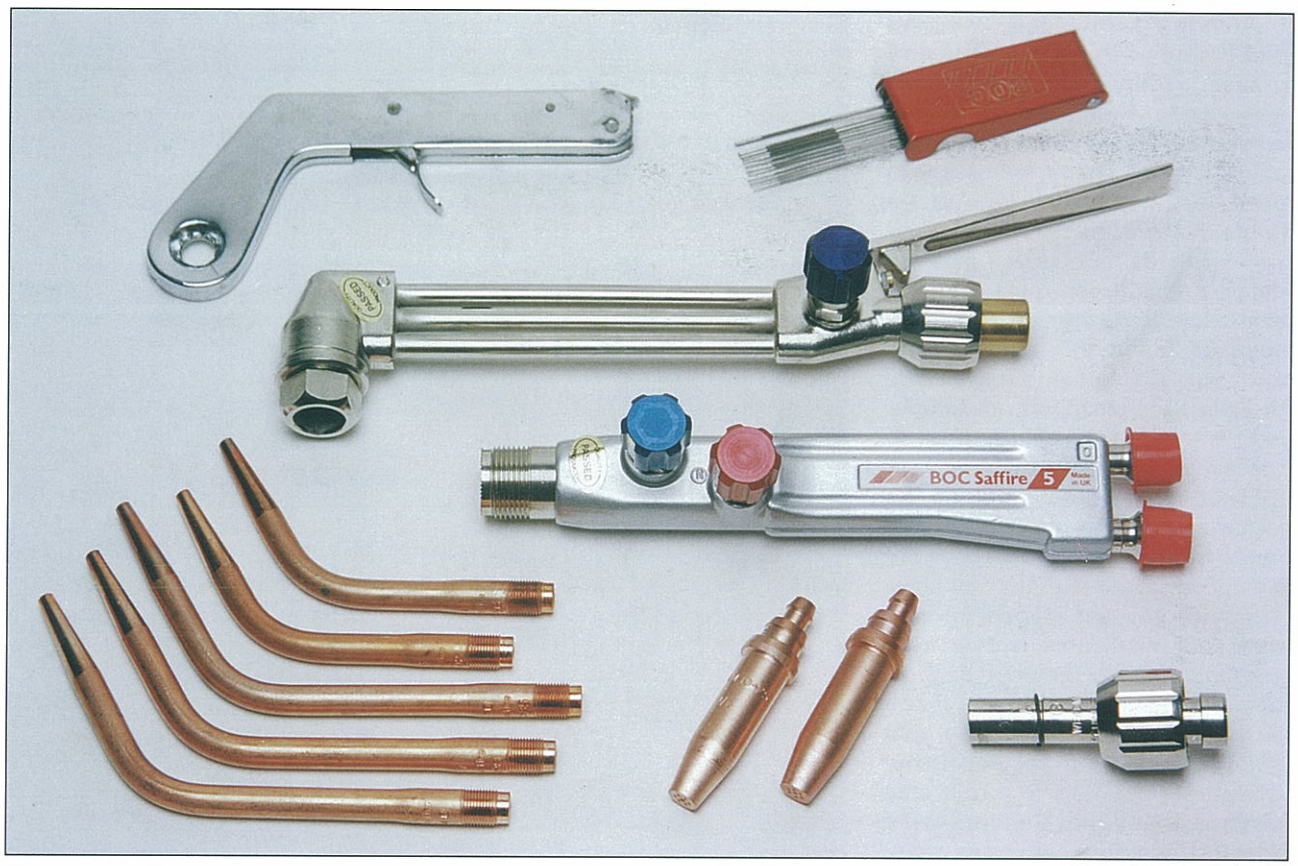


Fig. 1.2. A spark gun, set of nozzle cleaners, a torch, mixer and welding and cutting nozzles for a gas welder. (Steve Williams)

Mig welding

MIG (metal inert gas) welding is, in my opinion, the best method for welding your frame and other parts that need to be fabricated. I've instructed many people in this skill, and my student success rate has been 100 per cent. My usual method is to give direct one-to-one instruction for 30 minutes, familiarising the student with the controls and the techniques. I then give them a quiet work area with the MIG equipment, a big box of steel offcuts of all shapes and thicknesses, and leave them to practise. I check his or her progress from time to time during the day, advising and demonstrating as necessary, and by the end of the day everyone, without exception so far, has been sufficiently competent to weld a frame. By the time the frame is finished, they should be skilled and confident enough to fabricate brackets and all the other welded components required. I firmly believe that with the set of instructions provided with a new MIG welder, a person can teach himself/herself to MIG weld. The availability of small, low-priced MIG welding equipment has brought welding well within the scope of the DIY enthusiast.

Small MIG welders are available from some car accessory shops and tool shops, and the throwaway gas cylinders involved can be purchased over the counter for just a few pounds. Hiring is an alternative, and if you have your frame tubes already cut to length it should be possible to fabricate the frame over a weekend, thereby keeping hire costs to a minimum.

All welding is basically the same, but with a MIG welder you need an electric power supply. The equipment's controls should be set according to the instructions, but basically you have the power (or amperage) set low for thin steel and high for thick steel. The welding wire is on a spool or drum, and is fed through a tube to a nozzle which is held close to the joint to be welded. When you squeeze the trigger on the handgrip it activates a motor which feeds the wire through the nozzle to the joint. The material to be welded is attached to the welding equipment by an earth lead, so as soon as the wire touches the material it completes the circuit causing an electric arc. The wire and two pieces of metal to be joined immediately melt into a small pool and fuse together. Whilst this is happening, gas (either carbon dioxide or a carbon dioxide/argon mix – both being inert gases) from the cylinder attached to the machine also flows from the nozzle under pressure to surround the weld area, excluding

Fig. 1.3. A portable MIG welder. Remember you must wear a full-face shield to protect you from the ultraviolet light given off, and thick gloves should be used to stop your hands getting burnt. (Steve Williams)

any impurities from the immediate atmosphere and cooling the weld area. If you let go of the trigger, the arc, wire and gas flow stop, ready to be restarted by squeezing the trigger again. The arcing creates a very bright light, so your eyes must be protected by a special face mask. This mask will also protect your face from the ultraviolet light given off. The effects are rather like sun burn, so protect your hands with thick gloves, and also protect any other exposed skin. Keep children and animals well away, and if you have helpers or observers, provide them with face masks, too.

The only time I have experienced problems with MIG welding is when working outside in windy conditions, when poor welds can result because the gas shield is blown away. You can overcome this to some extent by turning up the gas pressure or, if that fails, by making a windbreak – sometimes just standing a box, or the welder itself on the windy side is enough.

Arc welding

Although small arc welders are very cheap to buy or hire, it takes a long time to develop the necessary skills (though not as long as with gas welding) and it is not really suitable for thin steel. The 16swg (standard wire gauge) tubes for your frame are about as thin as you can go with an arc welder, and whilst an experienced welder would make a good strong job of it, an inexperienced welder could well have difficulty with such thin material, and I would not recommend welding your frame as a first job. However, it is not impossible – but remember what I said about the need for patience.

Arc welding is not unlike MIG welding, as both use an electric arc to melt the metal to be joined, but instead of a continuous spool of wire, the arc welder uses rods, and instead of gas the rods are coated in a special flux which melts with the rod. When the weld has cooled,

the flux remains on the surface and needs to be chipped away with a special pointed hammer (a chipping hammer) to expose what, it is hoped, is a good weld beneath.

SAFETY PRECAUTIONS WHEN WELDING

- **Keep the area clear of combustible material.**
- **Always wear the correct eye protection.**
- **Wear strong boots and gloves, and thick overalls to protect yourself against sparks.**
- **Keep a suitable fire extinguisher close by.**
- **Do not allow electric welding sets to become wet or damp.**
- **Weld in a well-ventilated area and avoid breathing in fumes.**
- **Keep children and pets away from the work area.**
- **Keep oil and grease away from oxy-acetylene equipment.**
- **Keep gas cylinders upright and secured.**
- **Always turn off the gas supply and mains electricity when not in use.**

Fig. 1.4. Painting – two coats of grey primer and two coats of gloss paint will give a smart and durable finish which is easily touched up if damaged and, best of all, is cheap. (Steve Williams)

ENGINEERING SKILLS

If you've selected your donor motorcycle well, you should have no need to get into rebuilding the engine or gearbox, but you will have to overhaul and bleed the brakes, and fit brake pipes, etc. All the information you need will be in the *Haynes Service and Repair Manual* for your motorcycle, but you may like to back up this knowledge with evening classes at your local technical college or by joining a local motor or motorcycle club where you will find like-minded people who might well be interested in your project, and who may be able to help with knowledge, skills, practical help and even the loan of tools and equipment.

PAINTING

When the frame is complete it can be brush painted. Although I can spray paint, I still brush paint the frame, mainly because spraying a tubular frame is so wasteful of paint – there are more 'holes' than tubes.

As an alternative to painting, you may decide to have the frame powder-coated. This process will have to be carried out by a powder-coating specialist, and if you're not too fussy about the colour your frame ends up, you should be able to get a good price by having your frame coated at the same time as another batch of components.

Chapter 2
Tools, equipment and workshop safety

This Chapter lists all the tools and equipment required to build your Buggy. I'm acutely aware that we are producing a budget Buggy, and that the cost of the tools and equipment could exceed the cost of the finished project, but you'll probably have most of these tools already, or possibly you can borrow or hire them.

Included are several tools which, although not essential, will certainly enable you to tackle certain things more quickly and easily.

If you have to purchase tools, my advice is to buy the best you can afford, whether new or second-hand. If you look after them they will last a lifetime. Indeed, a large proportion of my hand tools belonged to my father and father-in-law. Remember, the best are not necessarily new. In fact, most of my metalworking tools and measuring tools have been purchased second-hand for just a few pounds, and I would not have got more effective or accurate tools had I bought them new.

BUYING TOOLS

Most large towns these days have hire shops, and I think it's worth considering hiring power tools or welding equipment if you do not already have them, but for small hand tools it's best to purchase your own, particularly if you can find good second-hand examples.

Car boot sales and autojumbles are the best source of second-hand tools and equipment. At these places it's expected of you to haggle, which is all part of the fun. Advertisements in local papers are also quite good for second-hand bargains. I've found not only tools, but also wheels, engines and complete donor motorcycles through such ads. One person I know who built his own car, bought a second-hand MIG welder, built his car, then sold the welder for a profit – that's enterprise for you!

The most important advice I can give you is to take your time collecting tools, equipment, materials and parts. There have been times when I've spent weeks looking for that elusive item, then after having purchased it new, a similar one has turned up at a fraction of the price I paid. So, remember, more haste – less cash saved!

To build the frame of your Buggy you're going to need some basic hand tools for measuring, cutting and shaping your frame tubes, and a welder for joining them together. Beyond that, you'll probably already have most of the basic tools required to build your Buggy. The following information will help you to decide whether you need to obtain any extra tools.

TOOLS REQUIRED

A very basic toolkit would comprise:

Basic hand tools

Socket set
Set of ring spanners
Set of open-ended spanners
Set of Allen keys
A small selection of screwdrivers
A selection of pliers/wire cutters
A selection of clamps
Large and small hammers
Steel tape measure
Steel ruler and set square
Hacksaw
Files – one flat, one round
Wire brush
Cold chisels and centre punch

Essential power tools

Electric drill with a selection of drill bits
Welding set

Bench tools

Vice (a Record No. 5 or 6, for example)
Bench drill

Specialist tools

The following specialist tools will be required to complete your Buggy, but as they will be used for a relatively small amount of work, you may wish to farm the work out to a helpful friend, a suitably equipped garage or a local engineering workshop. They will probably be only too glad to help when you tell them about your Buggy project.

Brake pipe flaring tool
Metalworking lathe
Tank/hole saw or jigsaw

Your Buggy can be built with just the previously mentioned tools plus a few basic household items such as scissors for cutting out card patterns, etc, and a pencil or a piece of chalk for marking out.

With regard to hand files, I

Fig. 2.1. A good quality set of sockets and spanners will last a lifetime. A selection of different lengths of socket-set extension is useful. Keeping your sockets on bars, as shown, will make it easier to select them for use and prevent them becoming lost. (Steve Williams)

Fig. 2.2. A useful selection of screwdrivers. (Steve Williams)

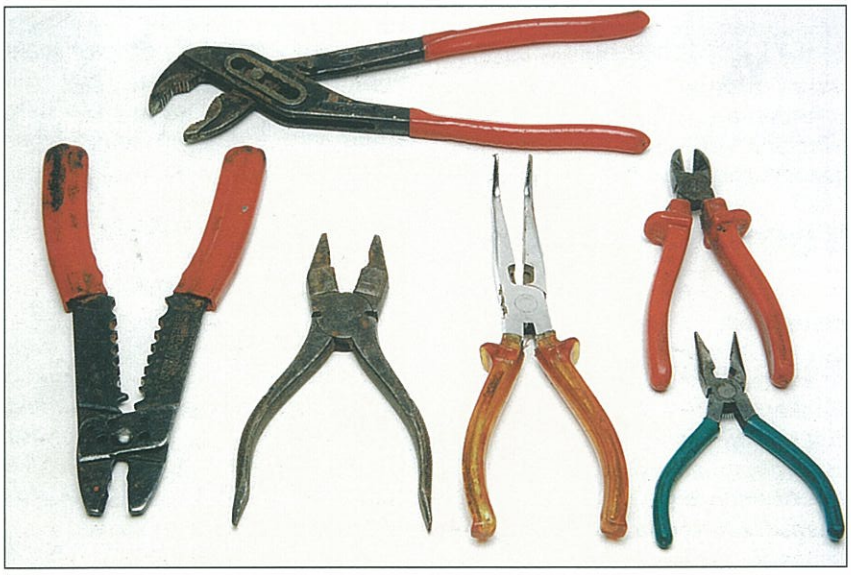


Fig. 2.3. A selection of pliers, including wire strippers and wire cutters. (Steve Williams)

Fig. 2.4. Wire brushes. (Steve Williams)

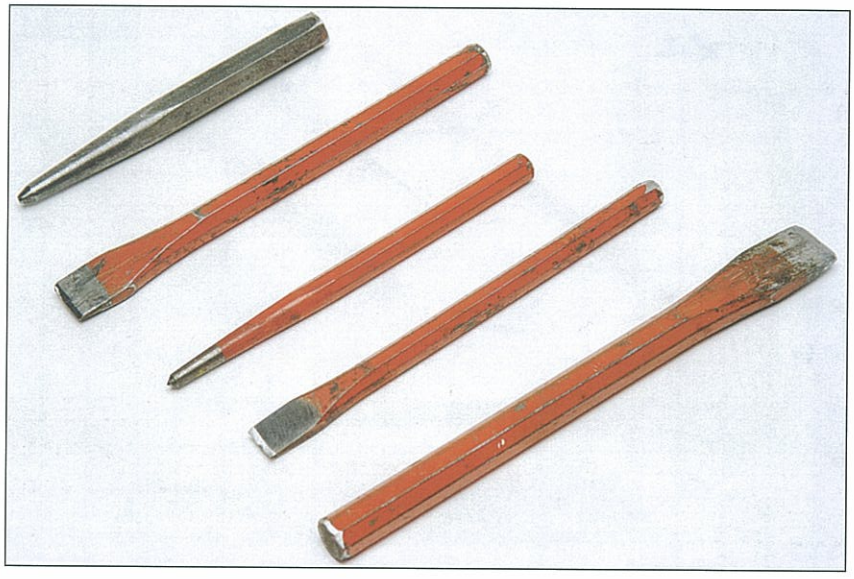


Fig. 2.5. Chisels and punches. Ensure that chisels and punches are kept sharp for accurate marking and punching. (Steve Williams)

would be the first to admit that an angle grinder could speed up the job considerably, as it can remove as much unwanted metal in a minute as a hand file can in an hour, but when keeping to a tight budget we have to remember that elbow grease is free.

Measuring and marking

A tape measure, a ruler and a set square are the most basic tools of metal working. Anything you produce without these will not be accurate. For workshop use, and particularly metalworking, you really need a steel tape measure and a metal rule, as plastic or wooden ones will soon become damaged and broken.

The ruler I use most of all is made of steel, one yard (around one metre) long, and only cost me a few pence years ago from a market stall selling second-hand tools. With some fine wire wool, rust was quickly removed and it has been used almost daily ever since. A small 6in steel ruler, 1/2in wide, is useful for work in restricted places.

A 10ft (3m) retractable steel tape measure is very handy to have – it helps you measure around curves and it fits neatly in your pocket for those trips to scrapyards, etc.

Set squares come in a variety of types and sizes, the only one I had for many years was a 12in x 6in (305mm x 152mm) carpenter's square, and this was used to build several space-frame chassis most accurately. I subsequently acquired a 24in x 18in (600mm x 450mm) roofing square which is proving invaluable for marking out larger areas. A combination square is a useful tool as it comes with a protractor head for measuring angles, and it also has a spirit level incorporated. If I've been away from my home workshop I've often

Fig. 2.6. Measuring equipment. A roofer's set square, a retractable steel tape measure, a carpenter's set square, a combination square and a 24in steel ruler. (Steve Williams)

Fig. 2.7. Cutting and marking tools for cardboard templates, etc. (Steve Williams)

Fig. 2.8. A profile gauge. (Steve Williams)

improvised and checked squareness with one edge of a notebook, or have made a quick triangle with an offcut of steel or aluminium sheet.

A centre punch is needed to mark metal for drilling holes. It makes a small indentation when struck with a hammer – essential to centralise the drill bit. The indentation holds the tip of the drill bit in position and stops it skidding and skipping across your workpiece as you start the drill.

You'll need a scriber for marking out metal, and one can be made from a broken or old screwdriver by grinding or filing the end to a point.

Something of a luxury is a profile gauge. These can be expensive new, but again can be purchased second-hand. They're particularly useful when working with round tube, and will help to give the correct profile of joints and brackets, etc, which are to be fitted to the tubes.

Cutting and shaping

A good quality hacksaw with a sturdy frame is essential, and it's worthwhile purchasing good quality blades – a quality blade will make the job quicker and will last longer. Take advice when purchasing blades, and always fit them so that the cutting teeth face the front, so that the blade cuts on the forward stroke. A wire-frame 'junior' hacksaw is ideal for tight areas or small jobs.

Files are used to give a smooth finish, or for shaping, by removing metal. They come in various lengths and shapes. The shape is the file's cross-section, which can be flat, square, triangular, round or half round. The teeth can be coarse or fine, or anything in between. A coarse or 'bastard-cut' file will remove a lot of metal quickly but will leave a rough finish. A 'second-cut' file will remove metal slowly and leave a smooth finish. The finest finish is achieved with a 'smooth-cut' file. The pointed end of the file is called the tang, to which is fixed a handle which always used to be wooden but is now quite often plastic. **Never use a file without a handle** or you are sure to have an accident.

Clamping

Clamps come in a variety of types, but all serve the same function of gripping two or more pieces of material together. The most common type is the G-clamp on which one adjustable face is moved by a screw thread. There are also lever-locking clamps which come in several designs and sizes. The specialist ones tend to be a little expensive, but I've found that I can make my own by buying locking clamps with worn out jaws, then making my own jaws from scrap and welding them on. In this

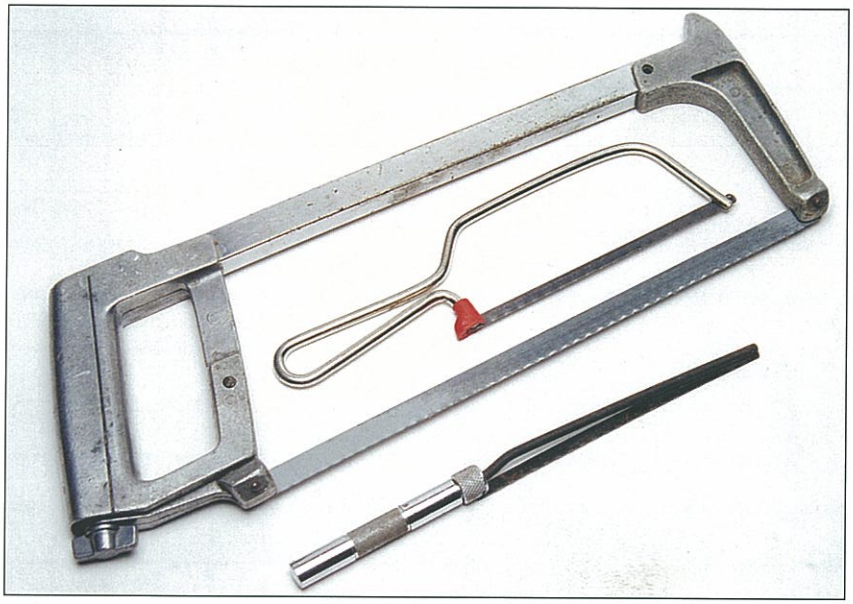


Fig. 2.9. Metal-cutting saws. Large hacksaw, 'Junior' hacksaw, and a very useful handle for holding a 'Junior' hacksaw blade when sawing in tight corners. (Steve Williams)

Fig. 2.10. A selection of files. It is essential that a correctly fitting handle is used at all times. (Steve Williams)

Fig. 2.11. A selection of self-grip clamps for holding metal items together when welding. (Steve Williams)

Fig. 2.12. A battery-operated rechargeable drill. Not essential if you have a mains-operated drill, but so light and compact to use. (Steve Williams)

way you can obtain a full set of specialist welding clamps for a fraction of their cost new.

The ideal vice for work on your Buggy project will have 5in (127mm) wide jaws. It will hold work safely when you're cutting, drilling, grinding and filing. You can also use it for clamping two pieces of metal together when welding, but remember not to let the heat get too close to the vice as this could damage it. Secure your vice firmly, and remember that a vice is only as secure as the bench it's bolted to.

Drilling and grinding

An electric drill is the one power tool that's almost indispensable. Apart from making holes it can be used to power grinding stones,

Fig. 2.13. Gauntlets and goggles. Essential for grinding and cutting operations. (Steve Williams)

rotary wire brushes and various types of sanding and buffing accessories **(and don't forget to wear goggles when using it for these purposes)**.

A note of caution: if buying this tool second-hand, please have it checked over by a qualified electrician. If the cable is frayed or damaged, or the plug wired incorrectly, the results can be fatal.

If you do acquire an angle grinder it will probably be the most potentially dangerous tool in your kit and, as with the drill, if buying second-hand, do have it checked by a qualified electrician and **always wear goggles and protective clothing (including strong gloves and ear defenders or plugs) when using an angle grinder.** The three main attachments for it are grinding discs, cutting discs and sanding discs which are used in conjunction with a flexible plastic backing. Used with care, an angle grinder will save hours of work and will produce a professional finish to your metal.

Welding equipment

As explained in Chapter 1, there are three main methods of welding – gas, MIG and arc. I would advise a beginner to obtain MIG welding equipment for two main reasons. The first is cost, as nowadays inexpensive DIY MIG welders are available both new and second-hand. The materials are inexpensive too, and – perhaps most important – with MIG a novice welder can produce first class results with minimal training.

An arc welder is cheaper to buy, but more difficult to master, especially on the material used to construct the Buggy. The welding is more violent, less easy to control and more inclined to burn through or blow holes in the workpiece. Another problem is that the welds form a black slag which has to be chipped away with a special pointed hammer, making it a messy and time-consuming process.

The other of the three methods is gas welding, involving two gas cylinders, one of oxygen and one of acetylene, together with hoses, gauges, torch and a welding or bottle trolley. This is probably the most versatile equipment of all, as it can be used for heating and cutting (useful for dismantling your donor motorcycle, as a little heat will release the most stubborn rusted nuts), bending and shaping, welding and brazing. But I have found that it takes longer to teach novices to gas weld, and certainly a greater level of skill is required than in MIG welding. It's also slower and, because of the greater amount of local heat generated, one of the major problems is heat distortion, which could affect the accuracy of your Buggy frame. Having said all that, the neatness of gas welding done by an expert is a joy to behold. It is not possible to purchase the gas cylinders outright. Instead, you have to enter into a rental agreement with the supplier, but it is possible to rent miniature cylinders (BOC Portapak). Although not aimed specifically at the novice or DIY market, they might help reduce costs and storage space. I think it would be fair to say, though, that this type of equipment is potentially more dangerous than other forms of welding.

WORKSHOP SAFETY

This is so important that I could fill a book just listing all the dangers and things to be aware of, but basically safety is down to just plain common sense. Think of your own safety, think of others, and think the job through before you start.

Every effort must be made to ensure a high standard of workmanship when building your Buggy. If in doubt, the author cannot recommend highly enough that you seek advice from a professional engineer or welder. At all times, work safely and with due consideration for others.

Power tools and welding equipment present the greatest hazards. Make sure that all your electrical equipment is safe (including extension leads), and if in doubt have it checked by a qualified electrician. Flying sparks from angle grinders and swarf from drilling can cause terrible eye injuries. When using any grinding, drilling, buffing, polishing, cutting or shaping power tools, wear safety goggles. Make sure the goggles are in good condition. If

you can't see what you're doing and are working part blind, it produces yet another hazard. Make sure you have goggles for helpers and spectators, as sparks can travel up to 20ft (6m). For welding, have an adequate mask or goggles, and be aware that gas welding goggles are for gas welding and not for MIG or arc welding. For these you use full-face masks. For any welding, wear protective clothing and gloves, making sure your arms are well covered. Keep all inflammable substances away from the workshop where you are welding or grinding.

Keep a clean and tidy workspace, and avoid trailing leads and cables, as these constitute tripping hazards.

As your Buggy frame takes shape it will need supporting at a safe and comfortable working height. Axle stands are ideal, but I also have several 18in (50cm) square wooden blocks which make firm supports. Do not be tempted to balance the project on bricks or boxes, as these may crumble or collapse.

Always keep a basic first-aid kit close by, and make sure other people know where it is. It also makes sense to have a fire extinguisher in your work area. One of the dry powder type suitable for electrical and liquid fires is ideal.

Ensure that there are no flammable liquids or materials stored in the workshop such as paint thinners etc. Remember most accidents can be avoided using common sense.

See also the welding safety precautions listed in Chapter 1.

Do's and Don'ts

- **DO** read this book from start to finish before starting the project.
- **DO** ensure that your welding is up to standard before starting work.
- **DO** purchase a first-aid kit and keep it in your work area.
- **DO** wear proper protective overalls, footwear, gloves and safety goggles when appropriate.
- **DO** get someone to check periodically that all is well when working alone in the workshop.
- **DO** keep loose clothing and long hair well out of the way of moving mechanical parts.
- **DO** seek professional advice if in doubt about safety related matters like brake and steering components.
- **DO** ensure that when working on the Buggy frame, the frame is supported securely on axle or chassis stands.
- **DO** ensure that all extension leads and cables on any power equipment are sound and free from cuts and damage, and check that the correct fuse is fitted.
- **DO** keep your work area neat and tidy, with no tripping hazards.
- **DO** mop up oil and fuel spills at once.
- **DON'T** smoke or allow naked lights (including pilot lights) anywhere near petrol or petrol vapour. Also beware of creating sparks (electrically or by the use of tools).
- **DON'T** weld without a fire extinguisher close by.
- **DON'T** weld without using an approved welding mask or welding goggles.
- **DON'T** work under vehicles supported by jacks, bricks, breeze blocks, etc.
- **DON'T** allow any inflammable substances to be stored in the workshop where you are welding or grinding, and this includes oily rags.
- **DON'T** use ill-fitting tools which may slip and cause injury.
- **DON'T** allow children or pets to play in or near a vehicle being worked on.

Chapter 3
Sourcing what you need

I developed the original concept of the Buggy when I was a school teacher and part-time youth worker, and variations were made on the theme in school and in various youth clubs. As such, this design is ideally suited for young people from the age of eight to sixteen. The whole philosophy behind the design and construction of the Buggy is to keep it safe, simple and cheap.

This book describes one way to build a Buggy, but it's not the only way. The book shows the basic design and is intended to get you started and to get you thinking. Skilled engineers might wish to modify the design, but my advice is to stay small and simple. If the design is varied, seek the advice of a competent engineer or someone experienced with off-road vehicles. The original design is tried and tested.

THE ORIGINAL BUGGY DESIGN

My original intention was to use a small-capacity engine such as the Honda 50 or 70. The advantage of an engine such as this is that it is still plentiful, cheap, has a centrifugal clutch and, therefore, two-pedal operation (go and stop). But, young people being what they are, there is always a temptation to fit larger and larger engines.

I feel that the maximum engine size safe for this design is 250cc, and even then one disc brake on the rear axle is starting to become overworked. It would be a simple matter to fit twin discs and calipers, but the real answer for a high-capacity engine would be front disc brakes. If anyone wishes to explore this route further, there are various publications available aimed at kart racers, and suitable equipment is readily available, both new and second-hand.

The original Buggy described in this book was built using as a donor a Yamaha 175cc motorcycle, which is normally a kick-start with a clutch-operated manual gearbox. This does mean that to start the Buggy you have to turn on the fuel tap, switch on the ignition, select a gear (probably 2nd or 3rd), depress the clutch and have a helper push you at a suitable speed. Release the clutch and the engine will start. However, in the past I've regularly started a kart single-handed by lifting the kart onto a block to raise the wheels clear of the ground, turning the fuel tap on, switching on the ignition and turning one of the back wheels until the compression stroke is felt, and then spinning and releasing the wheel. Once you've developed the knack it becomes a speedy operation. You've probably seen film of old aeroplanes being started by a member of the ground crew swinging on the propeller – the principle is the same.

However, most of the motorcycles and mopeds in the scrap yard have electric starts, which makes the process of starting a lot easier. The down side is that there is the complication of a battery, which will require maintenance and additional electrical wiring etc. Going electric or modifying a kick start is the easiest and safest way to go.

Fig. 3.1. The original Buggy on a high-speed run. (Steve Williams)

Depending on your choice of donor motorcycle, you may chose to make a Buggy with an automatic clutch/gearbox. I would recommend this for younger Buggy drivers, as piloting then becomes a two-pedal operation, using one pedal to go and one to stop.

For ease of construction and use, we have no suspension as such, the only suspension being provided by the low-pressure tyres, which for a small-capacityBuggy are ideal. Even high-capacity circuit karts don't have suspension, but this is because they run on tarmac. For an off-road vehicle with a high-capacity engine you really need to have long-travel suspension.

Again for ease of construction, I've used a solid rear axle on the Buggy, which drives both rear wheels. Normally, as there's no rear differential, there would be a tendency for the Buggy to travel straight on when the steering wheel is turned, but by careful design of the front steering geometry I've overcome this problem. Although having only one wheel driven would make the Buggy easier to steer, having two wheels driven helps to get the Buggy out of mud when stuck.

Donor motorcycles can be found with both hydraulic and cable clutches and brakes. For simplicity and ease of installation it's best to go for a cable-operated clutch, but a suitable car clutch cable should be substituted for the one from the motorcycle, as car clutch cables tend to be heavier duty and better able to cope with the greater force applied by a large boot rather than a hand on the handle bar. As you'll see later, hydraulic brakes are easier to install than cable brakes, so don't be afraid to mix and match parts from the scrap yard to get the combination you want.

I suggest that you read through the book before you start sourcing components, as this will enable you to weigh up some of the options available, and will help to ensure that you find the most appropriate parts for your own particular Buggy.

SOURCING THE PARTS

If, like me, you often work on vehicles of various sorts, you'll

Fig. 3.2. Bike breakers can be found all over the country – look in Yellow Pages*, local classifieds, etc. This yard has a good selection of Honda, Yamaha, Suzuki, MZ, etc, bikes. Very little in this picture would cost more than £25.* (Steve Williams)

probably have all sorts of parts lying around your garage or workshop, and you may well be able to put some of these to good use in your Buggy. For instance, I chose to use the Yamaha 175cc engine and gearbox in the Buggy appearing in this book purely because it had been lying forlornly in a corner of my garage for several years!

If you don't already have the components you need to build your Buggy, the first port of call should be your local scrapyard or motorcycle dismantler. It's a sad fact that the majority of motorcycle MoT failures end up in scrapyards because they are not worth repairing. Older, small-capacity motorcycles are so cheap and plentiful second-hand that if a bike fails the MoT test due, for example, to corroded wheels, or worn or seized brakes, it's often more economic to scrap the machine and buy another cheap example than it is to buy new parts or overhaul existing ones. Consequently, it's possible to find discarded motorcycles in scrapyards or at dismantlers that have many perfectly serviceable components in spite of having failed an MoT.

At the time of writing, the majority of these yards would collect a complete motorcycle free of charge, or pay the owner a few pounds if it was delivered to them. (The scrapyard would expect to recover anything from around £50 to several hundred pounds, depending on the type of motorcycle, from the sale of the major components, the remainder being crushed for scrap value.) Bear in mind that one of the advantages of visiting a scrapyard or dismantler is that you'll be able to mix and match components from various different motorcycles, rather than relying on a single donor for everything. If you go along to your local yard and have a chat with the manager, explaining to him that you want to use the components to build a Buggy, the chances are that he'll be sympathetic to your cause, and will let you have the parts you need for a reasonable price. However, if this fails, in order to get your donor motorcycle for the minimum possible cost, you need to purchase direct from the owner. How do you find the motorcycle you want?

First, it's worth going to the place responsible for the donor motorcycle being scrapped – the MoT garage. Tell them you're looking for a scrap bike, and explain to them what you want it for. With luck, they may already know of a suitable example that has failed the test recently, and be able to put you in touch with the owner; or they may be prepared to let you know when the next one comes along.

If this doesn't bear fruit, the second stage is to advertise in your local shop or newsagent's window. A typical advert would read:

Wanted
Honda C70
MoT failure or unroadworthy
Fair price paid
Contact: I. Wannabike
Tel. No. 01234 567890

Don't forget that the owner of this type of bike has probably been told by the scrapyard that it can be collected but no payment will be made, so your offer of a few pounds should not sound unreasonable.

It's also worth following the small advertisements in your local newspapers. Ask your friends to pass the word around at work and generally keep your eyes open.

WHAT YOU NEED FROM YOUR DONOR MOTORCYCLE

The following is a list of parts that you need to take from your donor motorcycle, and if you haven't tackled this sort of dismantling job before, it's worth buying a copy of the *Haynes Service and Repair Manual* for the relevant motorcycle. This will also be of help if you decide to overhaul any of the components, but keeping to the budget price means that there is not a lot of scope for this, and you need to ensure that, before buying the motorcycle, its engine, gearbox and any other

Fig. 3.3. This MZ motorcycle was for sale for £25. It was running, but had failed the MoT due to the exhaust. It has everything you need, including a hydraulic front brake. (Steve Williams)

components which you intend to use are in good running order.

Engine and gearbox (complete with carburettor, ignition system, exhaust system and clutch)
Chain
Sprockets
Front brake disc
Brake caliper
Hand-brake and master cylinder
Throttle cable
Various springs, clips, nuts, bolts, washers and brackets
Selection of nuts, bolts and washers to suit components removed from donor motorcycle

If you are using an engine with electric start in your Buggy, you'll need to take the associated wiring, a battery, and ideally an acid-proof battery box from the donor motorcycle.

Engine and gearbox

The Buggy described in this book uses an air-cooled, two-stroke engine (in this case a Yamaha 175cc unit). These engines are characteristically strong and reliable, although they tend to be noisier than equivalent water-cooled units and rev higher to achieve the same power. Four-stroke engines are often, but not always, water-cooled and tend to be quieter, lower revving and, at lower speeds, more user friendly which may be important for younger drivers. A major downside for a water-cooled engine is the need for a radiator and the associated plumbing. The radiator needs to be positioned in the airflow for efficient cooling and, on a vehicle that is likely to get some rough treatment, protecting it from damage could be difficult. The obvious position for the radiator would be above and behind the driver's head, but I would caution strongly against this, as in the event of damage or coolant spillage the last thing you want is boiling hot water over your head and down the back of your neck!

When looking for a suitable engine in the scrapyard, try to find a motorcycle that hasn't been stood out in the open for too long. Perhaps have a word with the yard manager, tell him what you're looking for, and tell him what you want to use it for. Invariably he'll be helpful.

My experience has shown that you'll be unable to get the engine to run in the motorcycle frame, because the battery will be flat or missing, or there will be vital components missing, such as an HT lead. Do ensure that the engine will turn over freely, and make sure that all essential components are present, such as the carburettor, gear-change lever, exhaust, etc. If the engine is from an accident-damaged bike, check thoroughly to make sure that there is no impact damage, and pay particular attention to the crankcase and various alloy covers. Try selecting all the gears – if you move the drive sprocket back and forth whilst doing this, it will help the gears to engage with a healthy click. Frequently there's superficial damage to the engine if the motorcycle has been dropped, but ensure that the covers are not distorted, which may give you oil leak problems.

Beware of any engine with a spark plug missing, as if water has entered, it will almost certainly have caused damage such as seized piston rings, and the gearbox components will be sitting in water, not oil, which will cause the gears to seize.

If possible, and if you're familiar with working on motorcycle engines, remove the cylinder head and check the condition of the piston and bearings.

Chain and sprockets

It's a good idea to check the condition of the chain and sprockets before removing the components from the motorcycle. To check the chain, shift the bike gearbox into neutral, then check the entire length of the chain for damaged rollers, loose links and pins and, on sealed chains, missing O-rings. If lubrication has been neglected, corrosion may have caused the chain links to bind and kink. If this is the case, any such links should be thoroughly cleaned and worked free.

The condition of the sprockets should also be checked – you'll probably need to remove the sprocket cover from the gearbox to check the drive sprocket. Check the sprocket teeth for wear and damage.

If any of the chain or sprocket components are excessively worn, and you're unable to find alternative second-hand components in good condition, you may have to resort to buying new components. Note that if you mix old and new components, you're likely to find that the new component(s) wear more rapidly than usual. It's good practice not to fit a new chain to old sprockets, and not

Alternative solutions

Automatic clutch

The Honda 70 is a strong, reliable, four-stroke, air-cooled engine with an automatic clutch and three gears. This engine will not run away with a youngster, and can be operated with just two foot controls – the accelerator and the brake. Additionally, both pedals can be operated with the right foot (as on a car), reducing the chance of the driver getting confused and operating both at the same time. This also provides the option of fitting a larger engine with a clutch at a later date – the clutch pedal could then be fitted in the conventional place and the driver would already be used to the accelerator and brake being in the correct place.

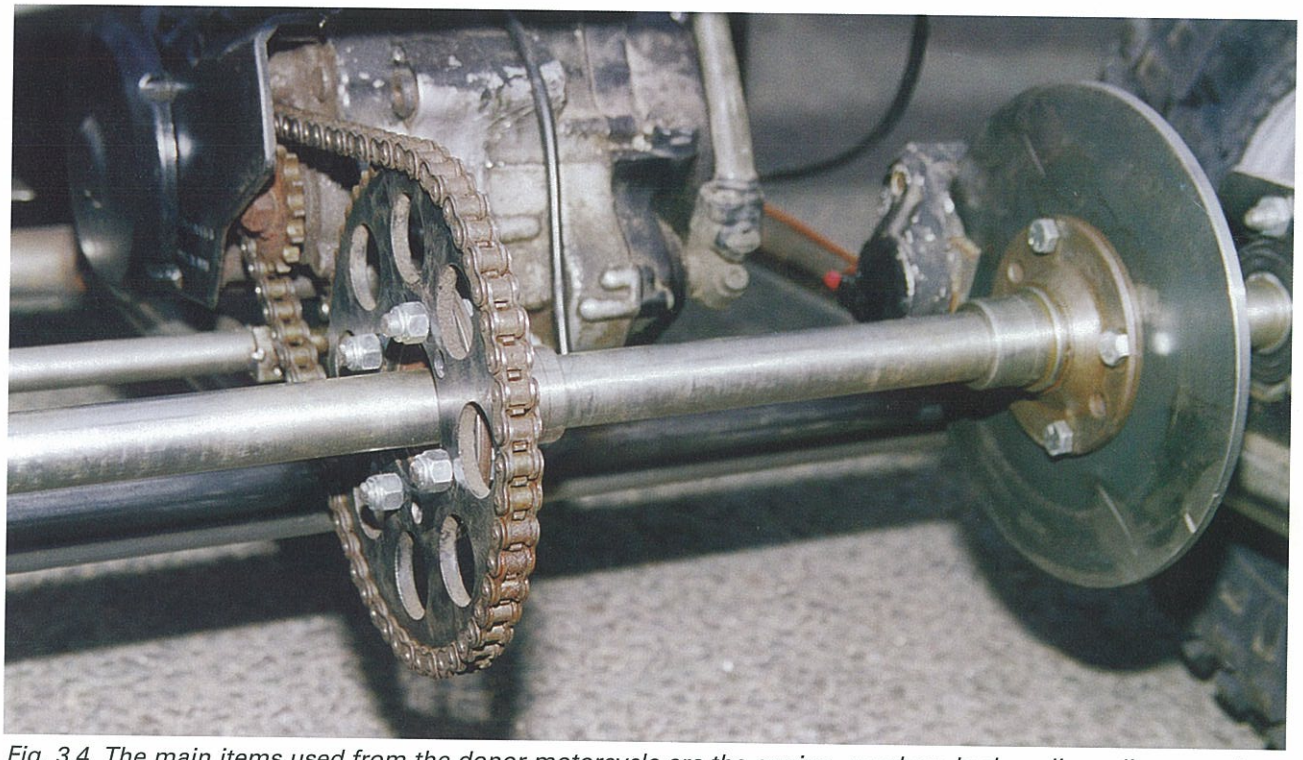


Fig. 3.4. The main items used from the donor motorcycle are the engine, gearbox, brake caliper, disc, sprocket and chain. (Steve Williams)

use the old chain if you fit new sprockets – renew the chain and sprockets as a set.

Brake components

Before removing the brake components from the motorcycle, check their condition as follows. Check that the disc is not pitted with rust, or scored. Try the caliper operation by squeezing the brake lever and moving the motorcycle forward. If the brake is in working order, it should not be possible to move the motorcycle. Equally importantly, when the handgrip is released, do the brake pads release from the disc? If they do, we're off to a good start. It may be worth dismantling the caliper and master cylinder with the aid of the relevant motorcycle workshop manual. Certainly renew the pads, and possibly renew the caliper piston seals and master cylinder seals. Please note that brake fluid is an effective paint stripper and melter of plastic, including some trainer soles. Take care not to get fluid in your eyes – if you do, flush out with plenty of water, and seek medical attention. I suffer from dermatitis caused by many years of exposure to brake fluid.

Fig. 3.5. A disc and caliper both in good order. The disc looks fairly new and you can see from the bright shiny surface finish that the bike was in use until recently. Beware of buying a donor bike that has been laid up for a while and has a rusty disc and, possibly, a seized caliper. (Steve Williams)

Fig. 3.6. This is a second-hand go-kart seat which cost £15, but the moulded seat from a stacking chair could be used and will only cost £1 to £2, if anything. (Steve Williams)

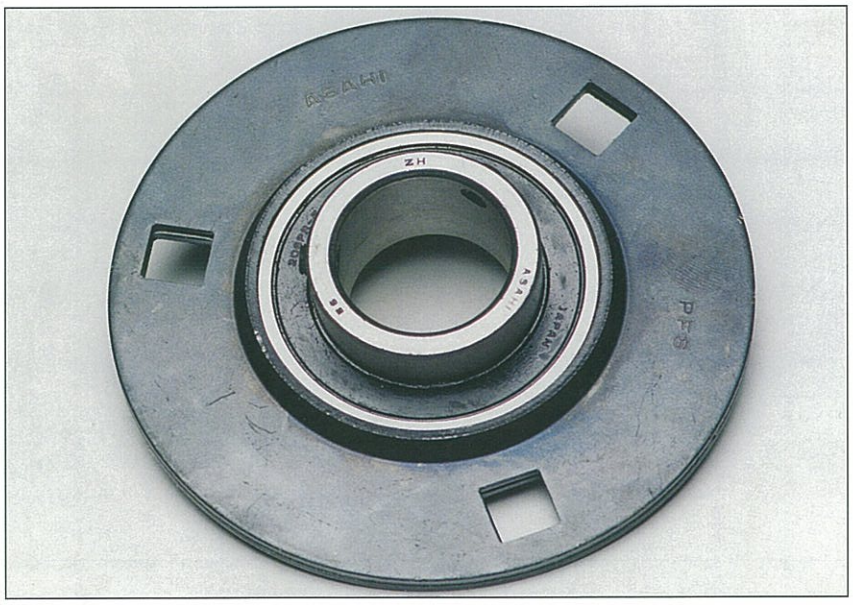


Fig. 3.7. Two of these proprietary self-centring bearings will be required. The internal diameter should match the diameter of the selected rear axle shaft. Look under bearing factors in Yellow Pages. (Steve Williams)

PARTS YOU REQUIRE FROM ELSEWHERE

Other parts required, additional to those taken from the donor motorcycle, are as follows. This list does not include the metal stock materials required, which are listed separately later in this Chapter.

Suffolk Colt lawnmower fuel tank, complete with on/off tap, fuel pipe and vented screw cap.
Two hose clips to suit fuel pipe
Four or six Ford differential flanges
Four quad-bike wheels and tyres
Steering wheel
Seat
2 self-centring bearings for rear axle
Conduit saddle clamp block for 19mm (3/4in) diameter conduit (for mounting steering column)
4 off track-rod ends (can be fabricated – see text)
8 off nuts to fit track-rod ends
3 bolts to fit through track-rod ends (with self-locking nuts)
1 bolt for steering column (with self-locking nut)
2 off M16 x 160mm long bolts for steering pivots (with self-locking nuts) (see note on following page)*
2m of 3/16in copper brake pipe and suitable fittings
4 off washers 3mm thick with 25mm diameter holes
4 off phosphor-bronze washers with 25mm diameter holes

2 off split-pins 3mm diameter x 40mm long
Assorted tension springs (to use as pedal return springs)
Clutch cable from car – see Chapter 8.
Accelerator cable from car – see Chapter 8.
Selection of split- pins
Assorted bolts, washers and Nyloc nuts
Cable ties
Paint and primer
Chain oil
Quantity of 2in nails for holding frame tube on board whilst welding
8ft x 4ft x 18mm board for marking out frame
*Note that the nuts and bolts obtained for use as stub-axle pivots must match the thick wall tube used for tubes U and V. Each bolt must be a good, but not tight fit, in the tube.

Fuel tank

The Suffolk Colt lawnmower fuel tank has a capacity of about one litre which will provide for about one hour of use. A lawnmower tank was selected because not only did it have a screw cap and an on/off tap which could be positioned so that the driver could reach it but because of the small diameter of the fuel pipe. While providing sufficient fuel for the engine the flow rate from the pipe would be low in the event of the pipe getting damaged. These types of fuel tank are readily available, even new, from lawnmower shops.

Ford differential flanges

The differential flanges used on the original Buggy were obtained from rear wheel drive Fords such as the Mk2 Escort, Cortina, Capri or Sierra.

The Buggy appearing in this book uses four flanges, one for each of the back wheels, one for the brake disc and one for the drive sprocket. If you're planning to use large wheels (fixed by studs or bolts) on the front of the Buggy, then a further two flanges may be required, one for each front wheel.

Fig. 3.8. A fuel tank from a lawnmower. Note the ventilated screw cap and on/off fuel tap, both desirable safety features. (Steve Williams)

Wheels and tyres

The original Buggy uses four quad-bike wheels and tyres, which were bought new from a farm machinery factors. These wheels and tyres are not cheap, but are perfectly suited for use on an off-road Buggy.

To keep costs down it would be worth keeping an eye open for some second-hand wheels and tyres or, alternatively, wheels from a small car such as a Mini could be used. Bear in mind that if

Fig. 3.9. A Ford differential flange, in this case from a Ford Capri, obtained for £2.50 from a scrapyard. (Steve Williams)

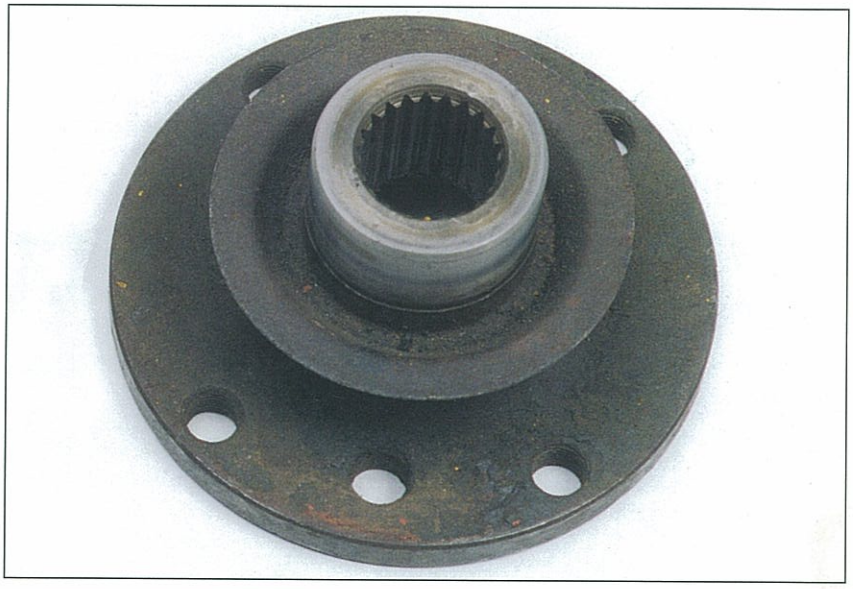


Fig. 3.10. These balloon tyres were sourced from a farm machinery factors and are usually used on quad bikes. The hubs have the same stud pattern as Mini wheels and come complete with bearings. (Steve Williams)

Ducks and dives

Seat

The original Buggy uses a bucket seat, but any alternative that fits within the Buggy frame can be used, provided it is comfortable for the intended driver.

A plastic stacking chair can be adapted to provide more support for the driver by fitting aluminium sides to it and securing with nuts and bolts or rivets to give it more rigidity and to make it more like a bucket seat.

conventional wheels and tyres are used, the Buggy's off-road ability will be somewhat compromised. It's also important to note that the diameter of the wheels determines the Buggy's ground clearance, so if very small diameter wheels are used, the ground clearance will be limited. A 6inch (150mm) ground clearance is the sensible minimum required. Also note that it's highly advisable to incorporate wheel bearings into the design – the wheels on the original Buggy run on needle roller bearings which are incorporated in tubes welded to each wheel.

THE STOCK METAL MATERIALS YOU WILL NEED (FACTORY OFFCUTS/SALE STOCK/NEW)

18m of 38mm (1½in) diameter round mild steel tube, with minimum 16swg (1.6mm) wall thickness – for Buggy frame
600mm x 600mm (24in x 26in) sheet of 1.6mm (16swg) thick steel plate – for Buggy floor
600mm x 600mm (24in x 24in) sheet of 5mm thick steel plate – for brackets and plates
400mm length of 30mm x 10mm flat steel bar (strip) – for front stub-axle carriers
320mm length of 25mm diameter round steel bar (or bar of a diameter to suit the front wheels/bearings you intend to use) – for front stub axles
800mm length of 19mm diameter, 1.6mm (3/4in) wall thickness steel tube – for steering column
1000mm length of 30mm diameter solid steel bar – for rear axle (see note on following page)*
140mm length of 22mm diameter steel tube, 3mm minimum wall thickness – for steering pivot housings, tubes U and V (see text)
1000mm length of 13mm diameter steel tube, with internal diameter

greater than the thread diameter of the track-rod ends you intend to use – for track rods
Length of steel tube to fit from gear-change splined shaft on gearbox to outer frame tube – see Chapter 8.
2000mm length of 20mm x 5mm flat steel bar – for pedals
*The rear axle is made from 30mm solid bar steel stock. When buying material to make the axle, take advice from the stockholder – hard steel must be used, not malleable steel, as if the axle is malleable, it may bend after rigorous off-road use.

Proprietary axles can be bought from karting specialists, in which case bearings and wheel mounting flanges can be bought to suit, although this is likely to be a more expensive option than making your own axle. Kart axles are designed to withstand the rigours of karting, so should be perfectly adequate for the Buggy.

Sourcing the steel materials

I found that I needed a work plan to ensure I made, sourced and purchased parts in some fairly logical order and, as the basis of the Buggy is the frame, onto which are bolted all the other components, it was decided to give early priority to sourcing the steel tube.

The Buggy's frame is a space-frame construction with round-section tubes, which makes an incredibly light and strong structure, resistant to loads both in compression and tension. The frame is made from a number of lengths of tube, but due to the lengths of some of the tubes, the longest being just over 2.6m, it's unlikely that you'll be able to source all the material required from offcuts. It should be possible to cut all the frame tubes required from three standard 6.1m lengths of tube, which can be bought from a steel stockholder.

When you go to buy the tubing for your frame, explain to the stockholder that you're going to use it to build a Buggy – this will help to ensure that you end up with the most suitable material for the job, and you may well find that if the stockholder is sympathetic to your cause he'll be able to find a few offcuts which will help to reduce the cost of the project. It would be a good idea to take along a list of all the metal materials needed to build your Buggy, as you're likely to be able to negotiate a good deal to buy all the materials from one supplier.

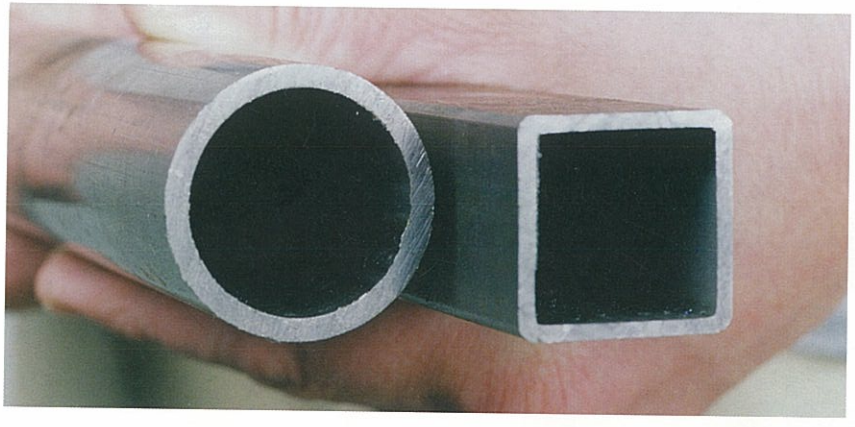
The wall thickness of the frame tubing should be at least 16swg. The 'swg' stands for 'standard wire gauge', a traditional standard for measuring not only the thickness of wire but also sheet steel and, in our case, the wall thickness of our tube. To help you identify it, 16swg is about 1/16in (1.6mm). The higher the number, the thinner the wall thickness, eg, 18swg is thinner than 16swg. 16swg (1.6mm) is the minimum wall thickness for the frame tubing. If the only material available is of thicker section or slightly larger diameter it will be quite suitable. Also, don't disregard SHS (square hollow section) or RHS (rectangular hollow section) tubing which are both quite suitable for the job. Some people might prefer the easier to cut mitre joints and angles you get when using RHS or SHS, instead of having to 'fish-mouth' the round tube. However in my opinion a frame constructed from round tube does look more pleasing and less agricultural.

I'm fortunate in that I live close to a town with a steel making and engineering tradition, and there are at least a dozen engineering companies and steel fabricators, all a source of offcuts. A search through your *Yellow Pages* will enable you to find such companies local to you. I advise a very polite and careful approach when requesting offcuts, and if you're refused it may be that they are mindful of safety and insurance regulations and don't allow visitors to rummage through scrap bins or skips. But, with a bit of luck you should be able to purchase all your steel quite reasonably.

A point worth mentioning is that if your tube is sourced from several different places, ensure that it's all to the same specification.

If you don't see yourself singing 'any old iron' round the metal merchants, you could purchase new standard lengths from your local steel stockholder, indeed it's advisable to do so for the main frame tubing.

Fig. 3.11. Samples of steel tube. If you get offered a good deal on square tube, don't be frightened to make the whole frame from square, although most feel that round tube looks better and gives a 'tougher' image. Whatever you do, do not go for material with a wall thickness of less than 1.6mm (16swg). We used material with a 3mm wall thickness. (Steve Williams)



Chapter 4

Making the frame

The Buggy frame is constructed entirely from 38mm (1½in) seamed round mild steel tube, with a minimum 16swg (1.6mm) wall thickness. You'll need about 18m of tubing. If you're purchasing new material from a steel stockholder, it's likely to be supplied in 6.1m lengths, and you'll therefore need 3 lengths to give the 18m you require. However, remember that you have to be careful with the way you cut the material up, because when you end up with two lengths 1m long, and you realise that you need a 1.4m long piece you can feel a bit silly! This is particularly important if the supplier is cutting the material up for you into 2 or 3m lengths so you can get it home in your car or on a trailer.

The strength and integrity of the frame will only be as good as the accuracy of your construction and the quality of your welding, so, this is the most important part of building your Buggy. Take great care with your measurements, and never feel ashamed at asking a qualified engineer and/or welder to check your work.

Fig. 4.1. The finished Buggy frame in all its glory! (Steve Williams)

WHAT YOU NEED

Tools required

Welding set
Welding mask or goggles, gloves, overalls and safety boots
Steel tape measure
Steel ruler and set square
Hacksaw
Files – one flat, one round
Wire brush
Tank/hole saw or jigsaw
Electric drill with a selection of drill bits

Materials required

For the frame you will need:
18m of 38mm (1½in) diameter round mild steel tube, with minimum 16swg (1.6mm) wall thickness – for Buggy frame
600mm x 600mm (24in x 26in) sheet of 1.6mm (16swg) thick steel plate – for Buggy floor
600mm x 600mm (24in x 24in) sheet of 5mm thick steel plate – for brackets and plates
Quantity of 2in nails for holding frame tube on board whilst welding
8ft x 4ft x 18mm board for marking out frame

CUTTING FRAME TUBES TO LENGTH

Please note that the dimensions given for the Buggy I built are intended to give a frame big enough for youths and adults, approximately 15 years old and upward. The actual dimensions of the tubes are not critical – variations are quite acceptable. Also, for the Buggy I built, I tapered the frame towards the front (ie, tubes A and B are closer together at the front of the vehicle than at the rear) for purely cosmetic reasons. The dimensions given in this Chapter for the tube lengths will enable you to construct a Buggy with a square frame (ie, tubes A and B are parallel), which is easier to build.

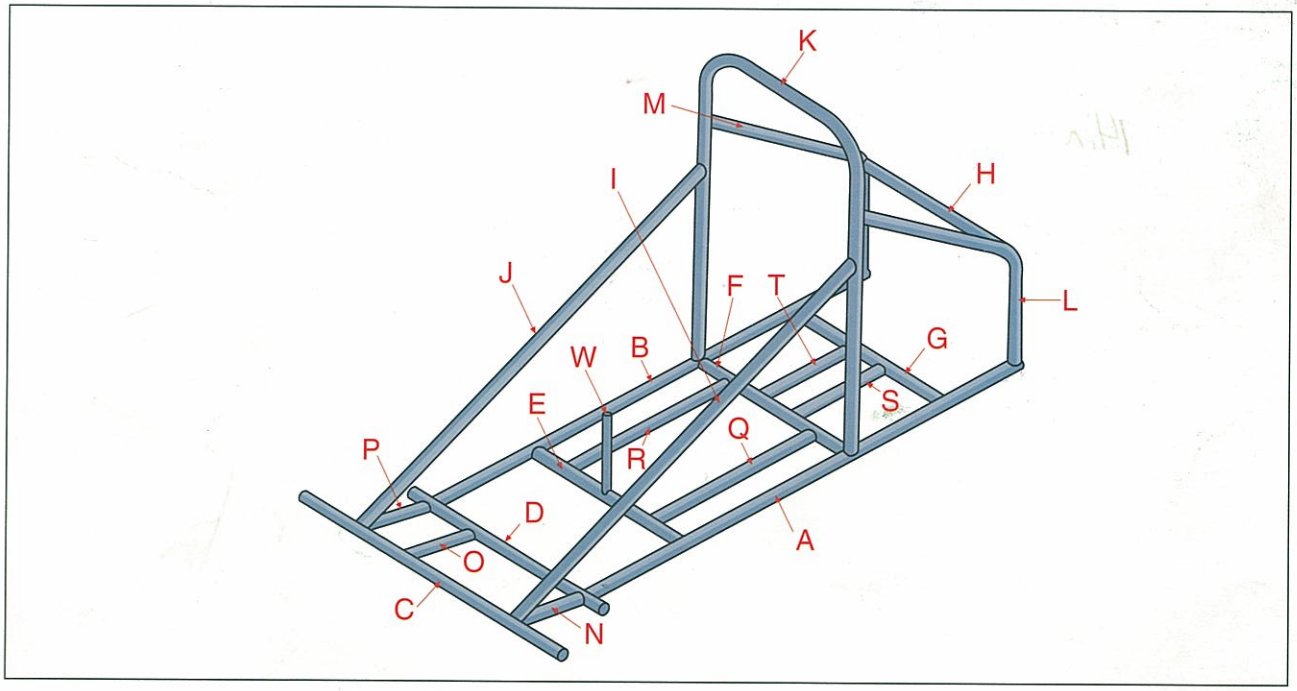
I would recommend that you don't cut all the tubes before you start constructing your frame, but instead cut tubes in pairs, tack-weld them in position and then measure the frame to find the required length for the next pair. Remember, measure twice cut once. It's a good idea to identify each length of tubing by marking it with a felt-tip pen. Take care when cutting to ensure that the tube ends are cut square, with the exception of one end of each of the tubes I, J, L and M, which need to be cut at an angle to ensure a correct fit with tube K. Tubes I and J need one end to be cut at an angle of 25° and tubes L and M need to be cut at an angle of 34°.

For details of the tubes required, refer to Fig. 4.2, and to the following cutting lists. The second list suggests how best to cut the lengths required from three standard 6.1m lengths of tube, which can be bought from a steel stockholder.

The following lengths need to be cut from the 38mm (1½ in) diameter, 16swg steel tube:

Tube	Length
A and B	1651mm
C	1016mm
D	760mm
E, F, G and H	600mm
I and J	1410mm
K	2650mm
L and M	1110mm
N, O and P	285mm
Q and R	630mm
S and T	360mm

Fig. 4.2. The complete Buggy frame showing tube identification letters.



Sample cutting list based on three 6.1m lengths of material:

Length No1		Length No2		Length No3	
Tube	Cut length	Tube	Cut length	Tube	Cut length
A	1651mm	C	1016mm	D	760mm
B	1651mm	E	600mm	J	1410mm
K	2650mm	F	600mm	L	1110mm
		G	600mm	M	1110mm
		H	600mm	P	285mm
		I	1410mm	R	630mm
		N	285mm	S	360mm
		O	285mm	T	360mm
		Q	630mm		

FISH-MOUTHING

To get a good fit when mating the round-section frame tubes together, with the exception of both ends of tube C and one end of tubes A, B and W, all the ends of the tubes must be 'fish-mouthed'.

This can be achieved either by hand, using a half or full-round file, or if you have access to a proper fish-mouthing machine then this makes the whole job easier. It may be worth visiting a local fabrication or engineering shop to see if they can do the job for you – look in your local *Yellow Pages*.

Fig. 4.3. A finished fish-mouthed tube. (Steve Williams)

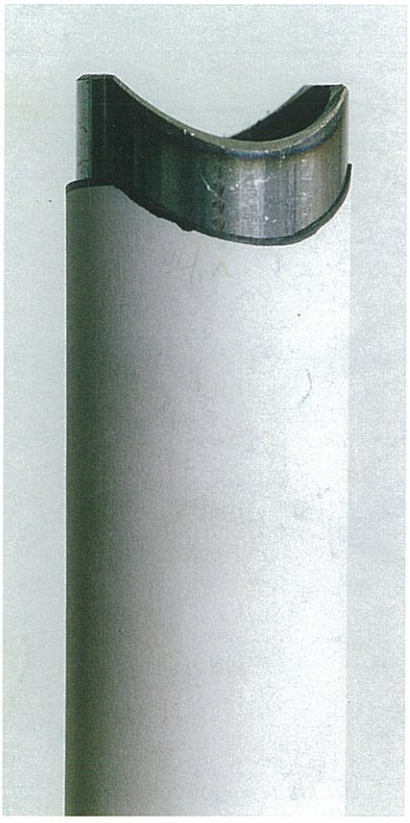
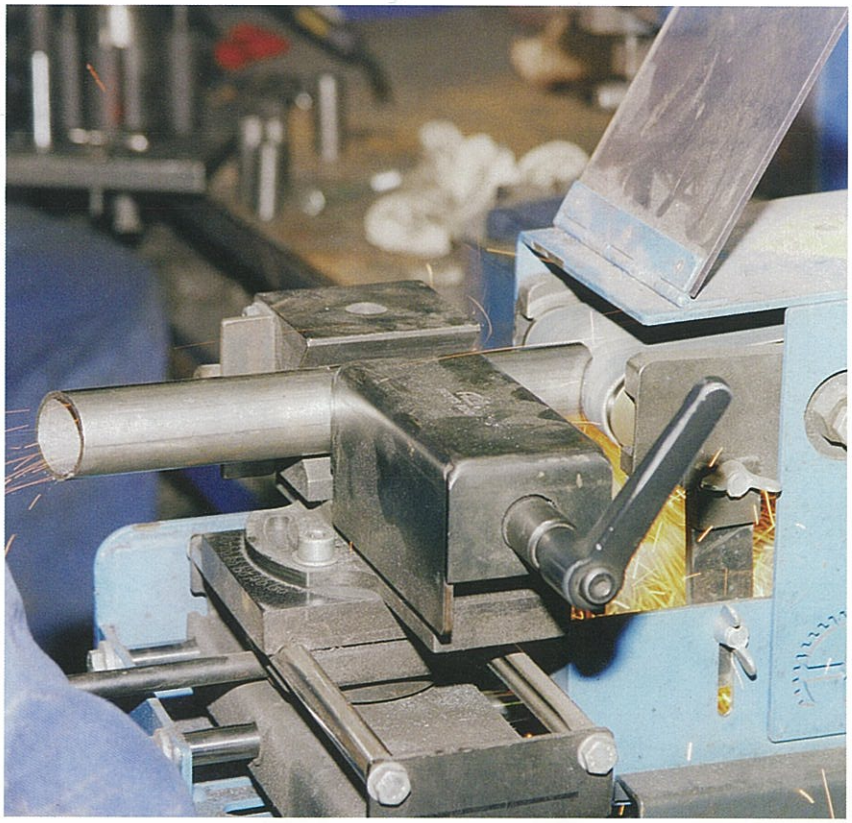


Fig. 4.4. Most people won't have one of these, but a proper fish-mouthing machine will make the job quicker an easier. (Steve Williams)

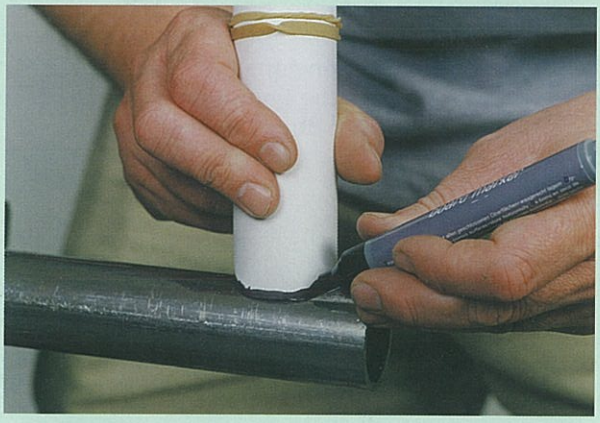


Ducks and dives

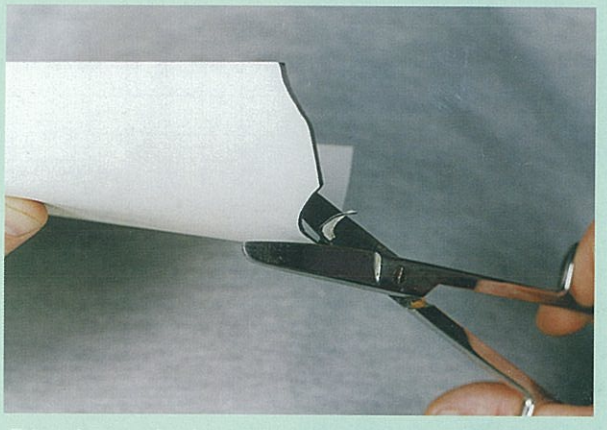
The toilet roll trick

To produce the fish-mouths on the ends of the tubes I've used the toilet roll trick. Refer to Appendix 1 for templates which can be used to fish-mouth tubes using 'The toilet roll trick'.

Using thin card, roll a tube of the same diameter as the steel tube to be shaped. To ensure the diameter is correct, the card can be rolled around the steel tube, and secured with sticky tape or elastic bands. Make sure that the card tube retains its shape when sliding it from the steel tube.



Hold the end of the card tube against the steel tube to be joined to, and mark on the card the approximate shape of the steel tube. (Steve Williams)



Trim the card tube with scissors to get a good fit. Ideally the fish-mouth should cover half the tube it is to fit. (Steve Williams)

Slide the cardboard tube over the steel tube to be shaped and mark the fish-mouth outline on the steel tube with a felt-tip marker pen. (Steve Williams)

File the tube to shape using a half-round file. (Steve Williams)

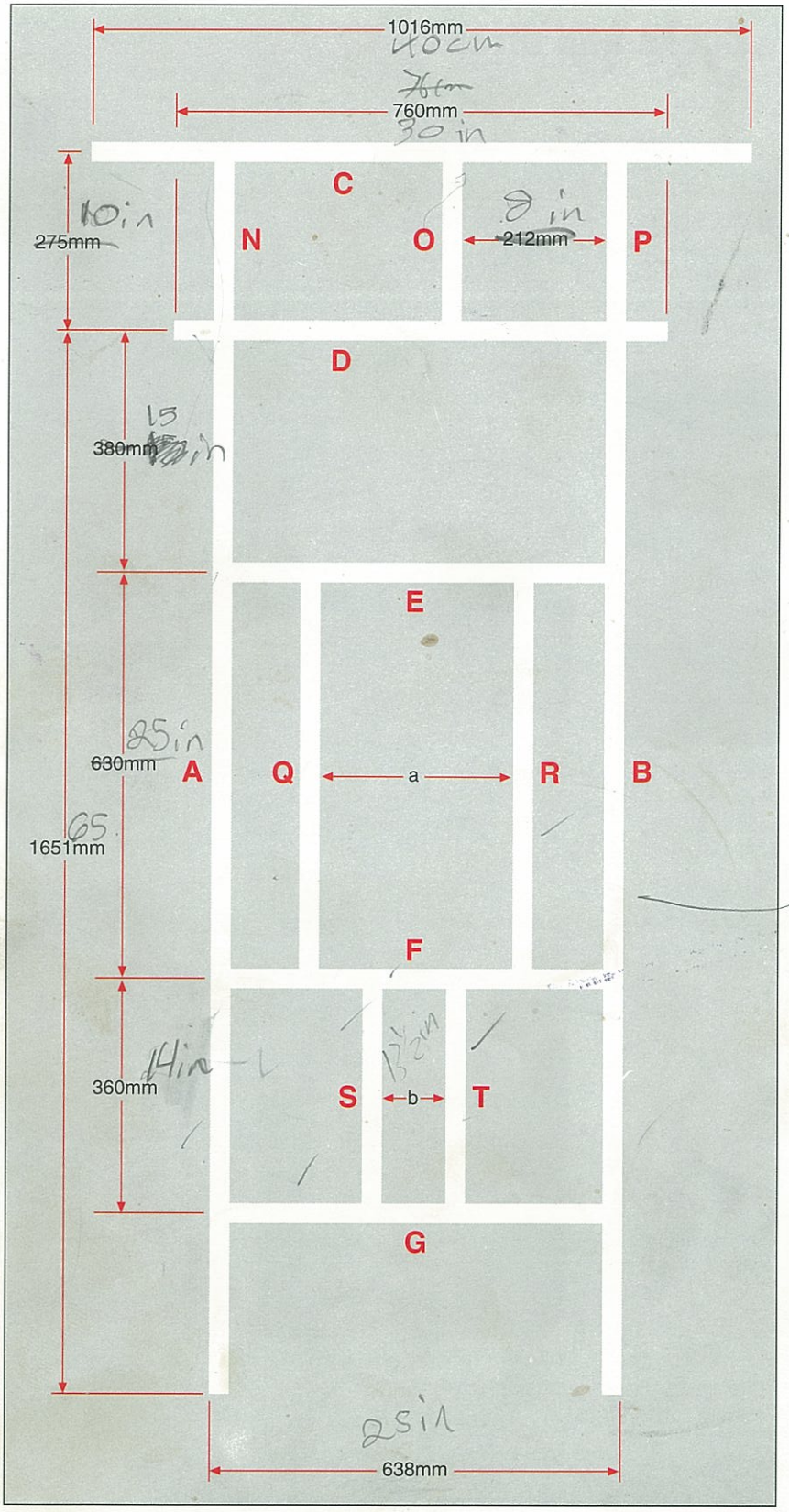


Fig. 4.5. Dimensions for marking out the frame building board showing the positions of the main frame tubes.

FRAME BUILDING BOARD

The building board provides a good flat surface on which to construct your Buggy frame. You may find it useful to mark out the positions of the frame tubes on the building board before you start. The distance between tubes Q and R (dimension a) is governed by the width between the fixing points of your chosen seat, while the distance between tubes S and T (dimension b) depends on the dimensions of the engine and gearbox you have acquired for your Buggy.

Fig. 4.6. The frame building board used for the original Buggy. Note that the frame tapers towards the front for purely cosmetic reasons. (Steve Williams)

hold with the nails. Place the kick-up sub-assembly in position against the main frame, supporting tube C on a 50mm high block to give the required kick-up. Position the sub-assembly so that tubes N, O, and P are correctly located on tube D of the main frame, then tack-weld into position.

The next tubes to be added to the frame are tubes Q, R, S and T. Tubes Q and R provide the support for the seat, while tubes S and T provide the support for the engine/gearbox mountings. I would suggest that you measure your frame from the centre line of tube E to the centre line of tube F at the required positions of tubes Q and R to make sure that the recommended cut lengths are still going to be correct. This check should also be carried out between tubes F and G to ensure that the cut length of tubes S and T are going to be correct.

When you're sure that you have the correct lengths for the tubes, cut and fish-mouth tubes Q and R, then position them on the board, hold the tubes with nails and tack-weld in position. Remember that the seat you are using governs the distance between the two tubes.

Now repeat the procedure with tubes S and T, but this time it's the engine/gearbox you have chosen and the distance between its mountings that will dictate the spacing required between the two tubes.

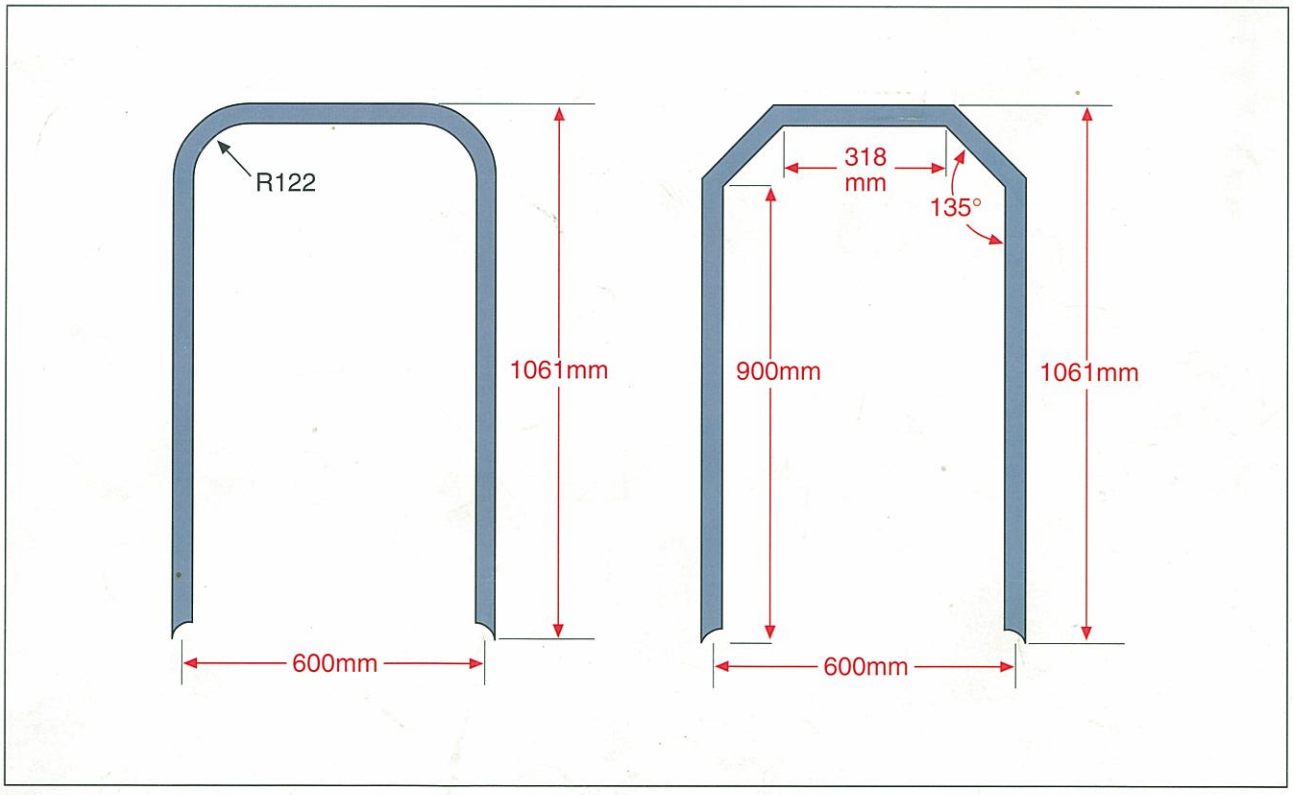
You now have the basic frame and it's time to fit the roll bar and the rest of the structure. The roll bar, tube K, can be made in one of three ways depending on the equipment available to you.

The photographs in this book show a Buggy with a roll bar which was produced using a tube bender. It's unlikely that the average home builder is going to have the necessary equipment to bend 38mm diameter tube, however it may be possible to hire or borrow a heavy duty pipe bender or to have the roll bar produced by a local fabrication shop.

Alternative methods of producing the roll bar are shown in Figs. 4.8, 4.9 and 4.10. Fig. 4.10 shows a roll bar which has had 'V's cut out to allow the tube to be bent, after which it has been re-welded. A simpler method is to cut and mitre the tube and make the roll bar out of five pieces as shown in Figs. 4.8 and 4.9. Having made the roll bar using your chosen method, it can be tack-welded into position on tubes A and B, ensuring that the roll bar (tube K) is positioned parallel to tube F on the main frame.

Mark onto the roll bar (tube K) the height/position where the side tubes I and J will join it, and measure the distance from the roll bar to tube C to ensure that the recommended cut length for tubes I and J is still correct. Cut and fish-mouth tubes I and J, remembering that one end of each should be cut at an angle of 25°. Position the square-cut end of tube I on tube C outboard of tube A, and position the angled end of tube I against the

Fig. 4.8. The dimensions for the roll bar. The roll bar can be formed either by bending or fabricating.



Ducks and dives

The angle trick

Use the corner of a square piece of paper or card to give you a 90° angle. Folding the paper diagonally in half will give you a 45° angle. Don't worry if this sounds crude – as a professional engineer I still reach for a piece of paper when I want a right-angle.

FRAME CONSTRUCTION

After cutting and fish-mouthing frame tubes A and B at one end, place them on the building board (fish-mouth end towards tube D) and hold them in position by knocking 2in nails into the board. Each tube can be held using four nails, two at either side of each tube at each end.

Next, prepare tube D by first cutting to length. Both ends of tube D require fish-mouthing, but to fit the diameter of tubes U and V (which house the steering pivot pins) and at an angle of 10° so that when tubes U and V fitted they are inclined towards each other, ie towards the centre of the frame, at the top (see Chapter 5, Fig. 5.5).

Place tube D in position on the board ensuring that the ends of tube D stick out equal amounts from tubes A and B. Also make sure that the fish-mouths of tube D are correctly orientated so that when tubes U and V are in position they will lean in towards the centre of the frame at the top. Additionally, the fish-mouths of tube D must be orientated so that when tubes U and V are in position they will lean towards the rear of the Buggy at the top, at an angle of 15° (again, see Chapter 5, Fig. 5.6).

Hold tube D in position with 2in nails, ensuring that the angles mentioned previously are correct, and tack-weld to tubes A and B.

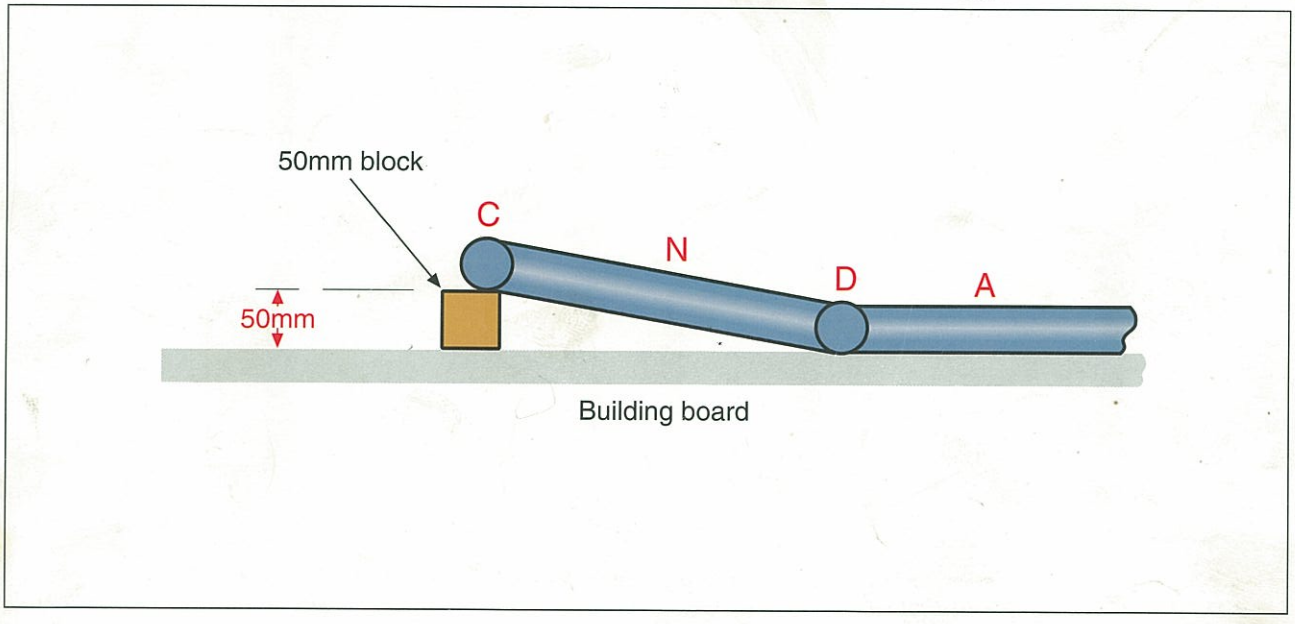
Cut and fish-mouth tubes E, F and G, place them in position on the building board, hold with nails and tack-weld to tubes A and B.

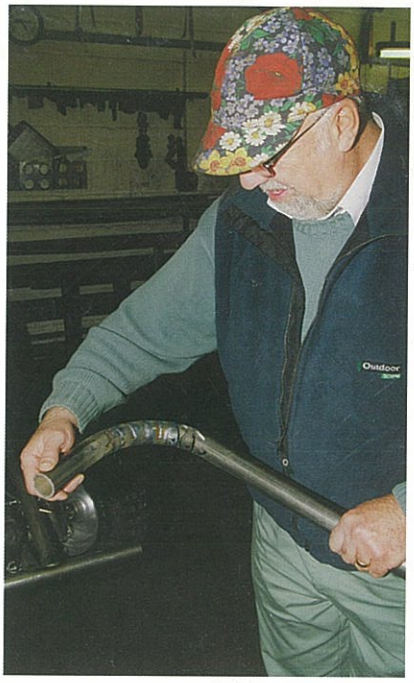
You'll now have to remove the assembly from the building board while you make the front kick-up sub-assembly. Even with only the tack-welds in place the assembly should be strong enough to move.

The front of the Buggy has a 50mm (2in) kick-up. Cut and fish-mouth tubes N, O and P, and cut tube C – remember that C is one of the few tubes which does not require fish-mouthing. This kick-up sub-assembly is first made as a flat assembly before being tack-welded to tube D to give the 50mm kick-up. Place tube C on the building board and hold in position with nails. Offer up tubes N, O and P and secure in the correct positions with nails, making sure that tube C sticks out equally beyond tubes N and P, and that the distance between tubes N and P is the same as that between tubes A and B on the main frame assembly. Note that tube O is not in the middle of the frame, but is offset to the right-hand side. Tack-weld tubes N, O and P to tube C. Also note that the dimensions for the frame layout shown in Fig. 4.5 take account of the 50mm kick-up, so when laid flat tubes O, N and P will appear longer than they are actually drawn on the building board.

Remove the front kick-up sub-assembly from the board, then manoeuvre the main frame assembly back into position and

Fig. 4.7. Method for ensuring the correct angle for the kick-up at the front of the Buggy frame.





Left: Fig. 4.9. An alternative method for producing the roll bar if you don't have access to a tube bender is to fabricate from sections of tube cut at an angle. (Steve Williams)

Above: Fig. 4.10. It's possible to produce a curved roll bar by cutting a series of 'V's out of the tube, bending it round and re-welding. (Steve Williams)

Left: Fig. 4.11. Main frame tube I tacked in position. Note the excellent fit produced by fish-mouthing the tubes. (Steve Williams)

roll bar (tube K). Tack-weld tube I in position, and then repeat the procedure on the other side of the frame with tube J.

Tubes L and M require cutting, fish-mouthing and then bending or mitring in a similar fashion to the roll bar (tube K) – see Fig. 4.12. Note that one end of each of the tubes should be cut and fish-mouthed at an angle of 34° to allow it to mate to the roll bar (tube K). Once made, tubes L and M can be positioned on tubes A and B and

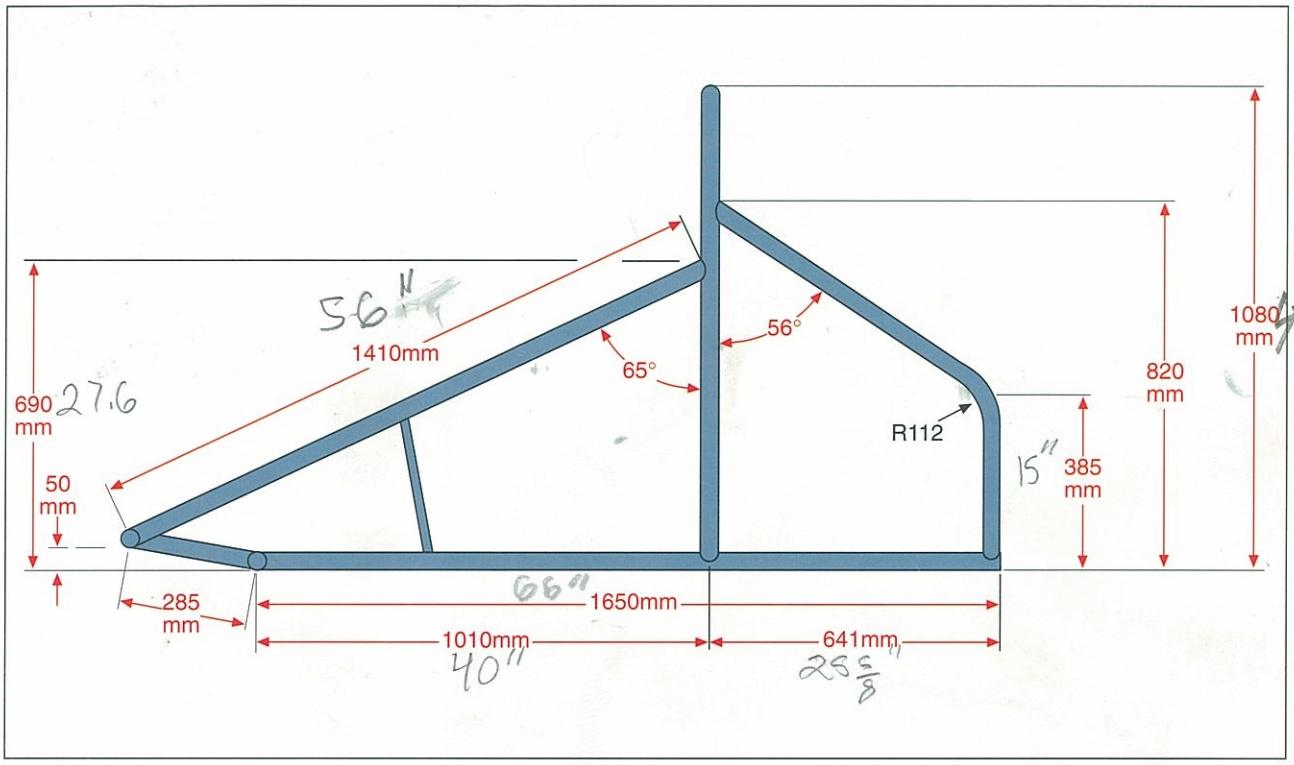
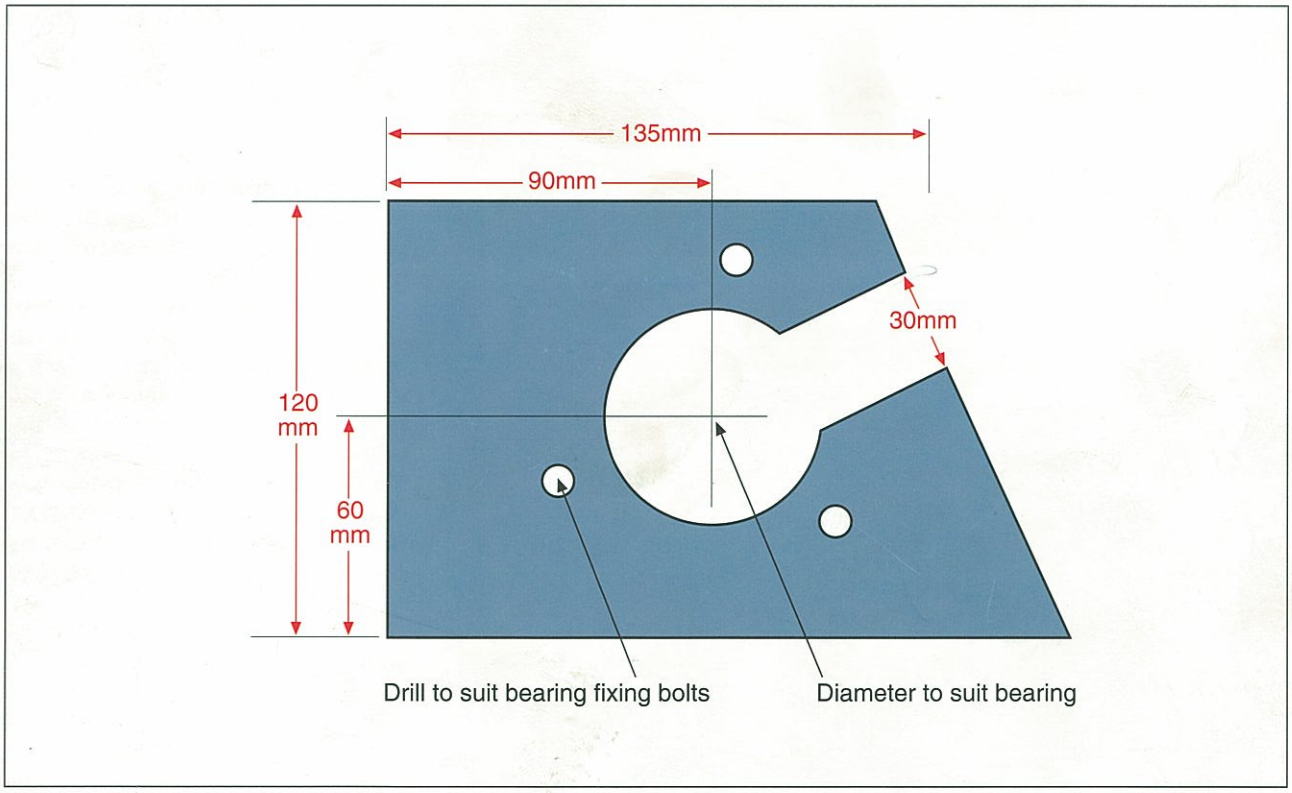


Fig. 4.12. Side view of the frame showing the dimensions and positions of the main frame tubes.

Fig. 4.13. The bearing mounting plate needs to be made to suit the bearings you have purchased. The 30mm wide slot is to allow the rear axle assembly to be removed without having to remove the sprocket, wheel hubs, bearings, etc. It, therefore, needs to be slightly wider than the diameter of your axle.



Ducks and dives

The string trick

In awkward places, or when you want to measure round corners or funny shapes, I find that a piece of string can be useful tool. Use a piece of string to find the distance you want, and then it's easy to measure the length of the string once it's straightened out with your tape measure.

mated up with the roll bar before being tack-welded in place.

The last frame tube to be fitted is tube H, which fits at the rear of the frame between tubes L and M. Tube H should be positioned in the centre of the bend in tubes L and M. Measure the distance between tubes L and M to check that the recommended length for tube H is correct before cutting. Once the tube has been cut and fish-mouthed, tack-weld it in position.

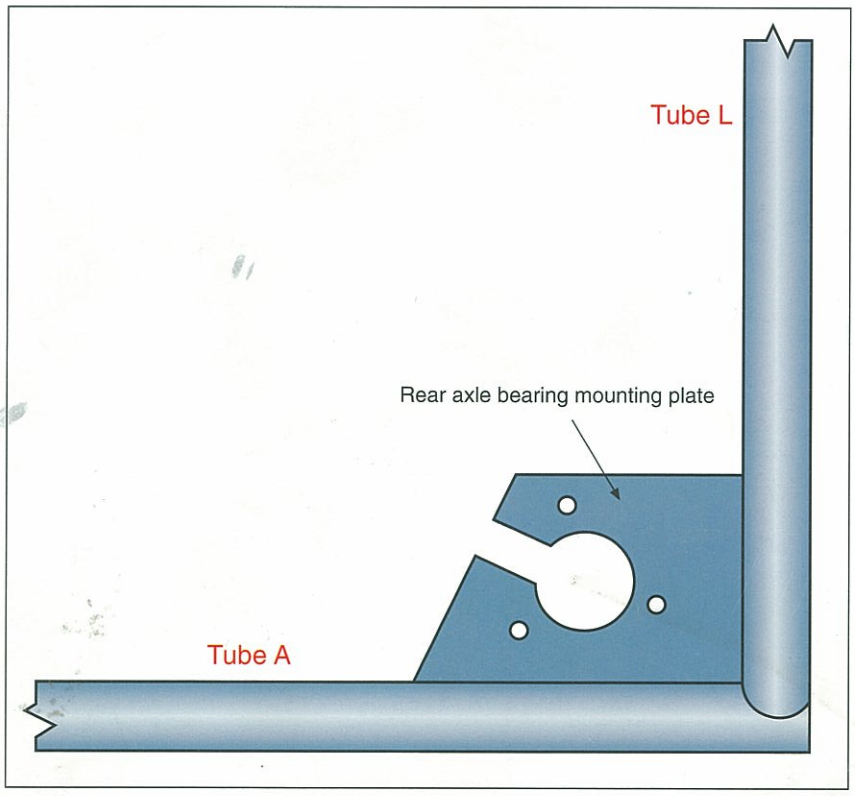
The bare frame is now complete, and all the components have been tack-welded in position, however before final welding, the various mounting plates and brackets should be made and fitted to the frame as follows.

REAR AXLE BEARING MOUNTING PLATES

From your piece of 5mm steel plate mark out and cut the two rear-axle bearing mounting plates – see Fig. 4.13. The outside profile of the plates can be quite easily cut using a hacksaw or an electric jig saw. The holes for the bearings can be cut using a tank/hole saw or, again, can be cut out with a jigsaw. The bearing holes and fixing bolt holes should be cut to suit the bearings you've purchased.

Once the correct position of the mounting plates has been determined, they can be tack-welded in position on the left-hand side of the frame where tube A joins tube L, and on the right-hand side of the frame where tube B joins tube M.

Fig. 4.14. The bearing plates are positioned on the left-hand side of the frame where tube A joins tube L, and on the right-hand side where tube B joins tube M.



ENGINE/GEARBOX MOUNTING PLATES

Cut the engine/gearbox mounting plates from 5mm plate. These you'll have to make to suit your chosen engine/gearbox – Fig. 4.15 shows the ones I used for my Yamaha 175cc unit.

To determine the size and shape of the mounting plates, stand the engine/gearbox in the back of the chassis in the approximately required position. Before attempting anything else, satisfy yourself that you have access to the kick-start mechanism, if required, and that the engine is in the original attitude that it was mounted in the bike frame – this is essential for the correct working of the carburettor float chamber and the engine lubrication system (the dipstick and oil filler plug are only accurate with the engine mounted in its original attitude). Once the engine/gearbox is located correctly in the frame, look at the existing lugs on the crankcase and make up brackets to mount the engine in the Buggy. If desired, additional frame tubes can be added to aid engine/gearbox mounting. Note that the mounting brackets should be of at least equal thickness to the original brackets used to mount the unit in the bike. To make the process easier, use wooden dummy brackets or stiff card templates, mark the shape of the bracket(s) and the positions of the mounting bolt holes, and then transfer the marks to the metal plate.

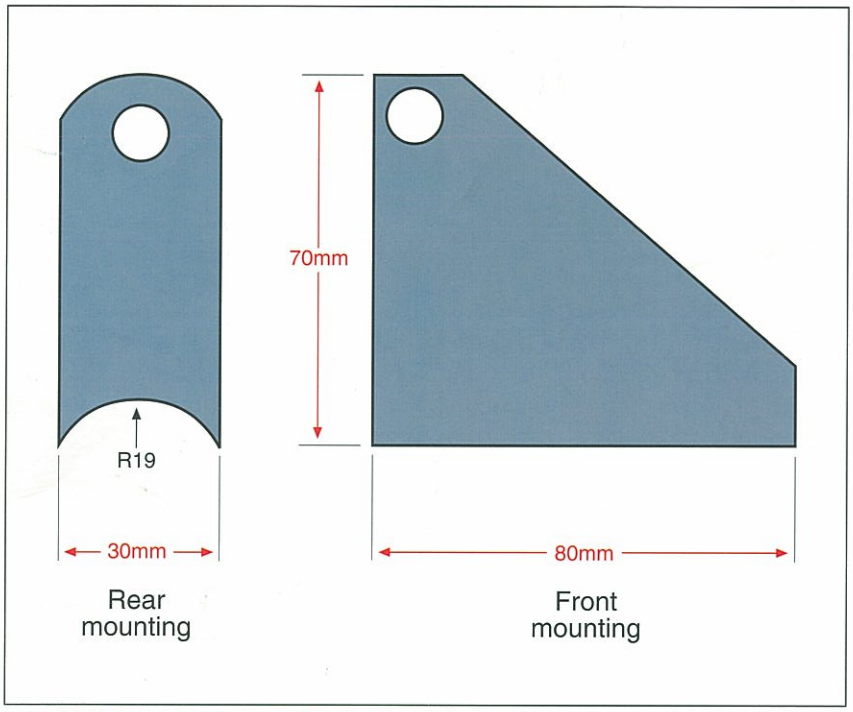


Fig. 4.15. You will have to make mounts to suit the engine/gearbox from your donor motorcycle. These are the ones I made for my Yamaha 175cc unit.

Once you've decided on the size, shape and position of the mounting plates, they can be cut out using a hacksaw or an electric jigsaw. At this stage you can drill the mounting holes for the engine/gearbox, but it would be a good idea to wait until the plates have been welded to the frame and the rear axle has been trial fitted – this will enable you to drill the holes in the right place.

On some engines, such as the Honda 50 and 70, it may be possible to produce an engine mounting plate with slotted holes to allow adjustment of the chain tension. Alternatively, to allow chain tension adjustment, use elongated holes for the rear axle mounting (but note that these cannot be used with self-centring bearings).

When you're sure that you have the correct mounting plate positions for your particular engine/gearbox, the plates can be tack-welded in place. For the engine/gearbox I used, the front plates were tack-welded to tubes S and T, and the rear plates were tack-welded in place on tube G. You may, of course, need to vary this arrangement, according on the mountings fitted to your chosen engine/gearbox.

Fig. 4.16. One of the two front engine/gearbox mounting plates. This one is shown fully welded. (Steve Williams)

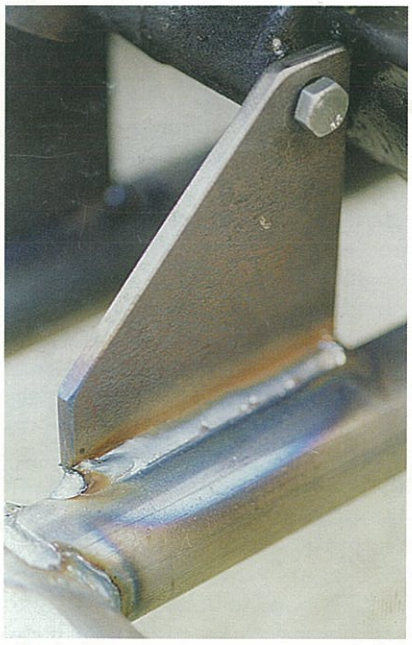
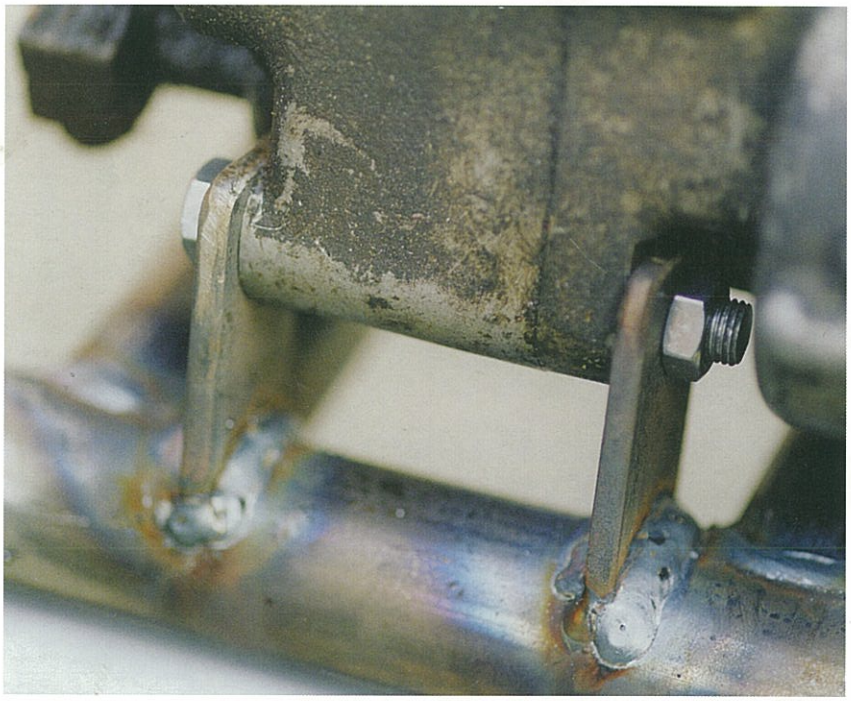


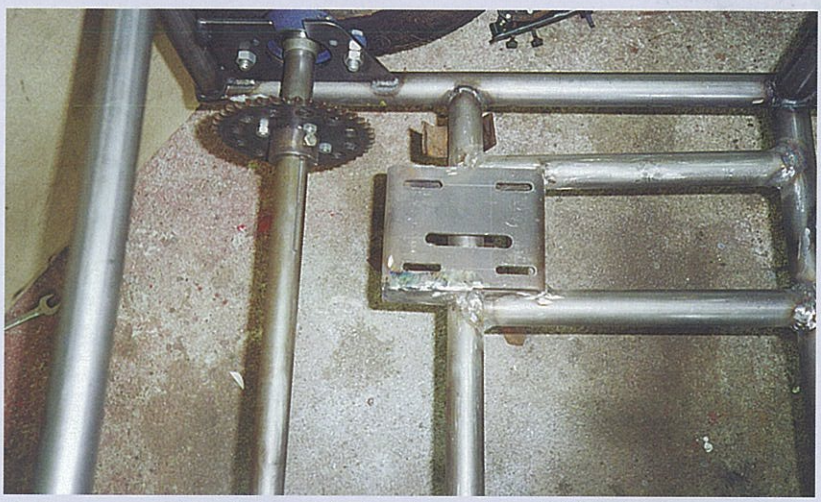
Fig. 4.17. The rear engine/gearbox mounting plates. Again, fully welded. (Steve Williams)



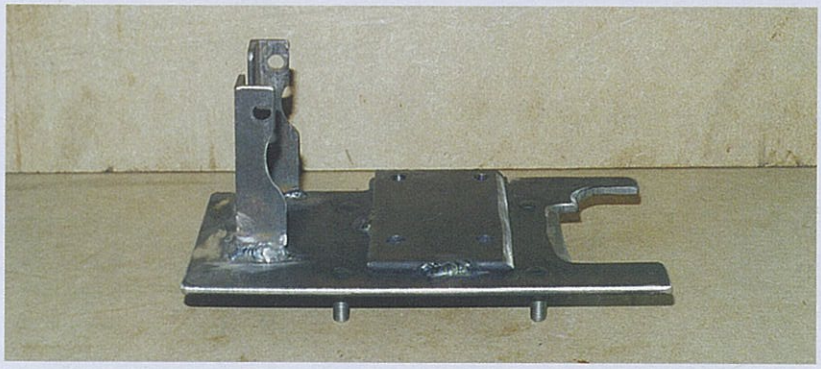
Alternative solutions

Adjustable engine/gearbox mountings

To enable adjustment of the chain tension, the engine/gearbox mountings can be designed to allow the engine/gearbox position to be altered slightly. For the Honda 70 engine, this can be achieved using two flat plates, one bolted to the engine, and one welded to the frame. The arrangement shown here was loosely copied from a racing kart. The plates should be wide enough to fit between frame tubes S and T. Drill the top plate to accept four bolts, which will be used to bolt the top plate to the bottom plate. With the top plate drilled, clamp the two plates together, mark the locations of the holes in the top plate on the bottom plate, then drill corresponding holes in the bottom plate. Cut the heads off the four bolts, then weld the bolts in position in the holes in the top plate, so that the ends of the bolts are flush with the top face of the plate. Elongate the holes in the bottom plate to allow the top plate to slide backwards and forwards for adjustment. Weld suitable brackets to the top plate to allow it to support the engine/transmission (on the top plate shown here an additional plate was welded to the top plate to help support the engine/transmission). Weld the bottom plate in position on the chassis between tubes S and T, and bolt the top plate to the engine/transmission. The engine/transmission can now be fitted by lowering into place, making sure that the bolts welded to the top plate pass though the elongated holes in the bottom plate. Fit Nyloc nuts to the ends of the bolts, then adjust the position of the engine/transmission as necessary and tighten the nuts.



Bottom mounting plate welded to frame. (Derek Manders)



Completed top mounting plate with brackets welded in position. The holes in the brackets align with the original footrest mounting points on the engine. (Derek Manders)

Top mounting plate in position on engine/transmission. (Derek Manders)

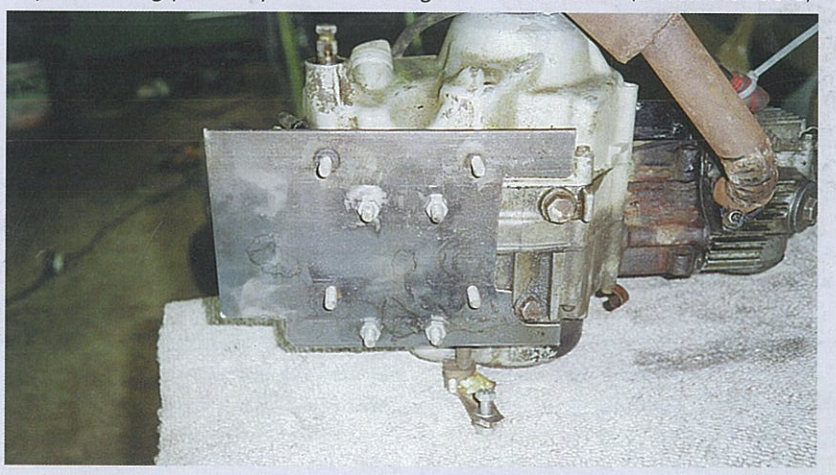


Fig. 4.18. Seat mounting plates welded in position. These have only 4 holes drilled for a non-adjustable seat. If you want the position of the seat to be adjustable, then you can drill a series of holes. (Steve Williams)

SEAT MOUNTING PLATES

Again from the 5mm plate, cut two seat mounting plates approximately 45mm x 400mm to suit the seat that you have. At this stage you can drill the fixing holes for the seat, but it would be a good idea to wait until the plates have been welded to the frame and the pedals and steering wheel have been fitted – this will enable you to drill the holes in the right place. If more than one person is likely to use the Buggy, or if you want to allow for someone who is still growing, you can drill a series of holes to allow the seat to be moved forwards or backwards.

Once you're happy with the size and positions of the mounting plates, tack-weld them in place on tubes Q and R.

FINAL WELDING OF FRAME AND MOUNTING PLATES

It's suggested at this stage that, if not already done, the axle and the engine are trial fitted to check that the mounting plates are in the right place. When you're happy with the position of all the mounting plates, the frame can be fully welded. To help prevent distortion, weld alternate sides – for example weld joint C/I followed by joint C/J, then weld joint K/I followed by K/J, etc.

FLOOR

When your frame has been fully welded, cut the floor panel from the 1.6mm steel plate. This can be made in either one or two pieces. If making it as one piece then you can either pre-form it to give the 10° kick-up at the front, or weld the kick-up in position on tubes C, D, N, O and P before clamping the remainder of the plate in position on tubes A, B and E and welding. If making the floor in two pieces, one piece can be used to panel in under tubes C, D, N, O and P, and the other to panel in between tubes A, B, D and E.

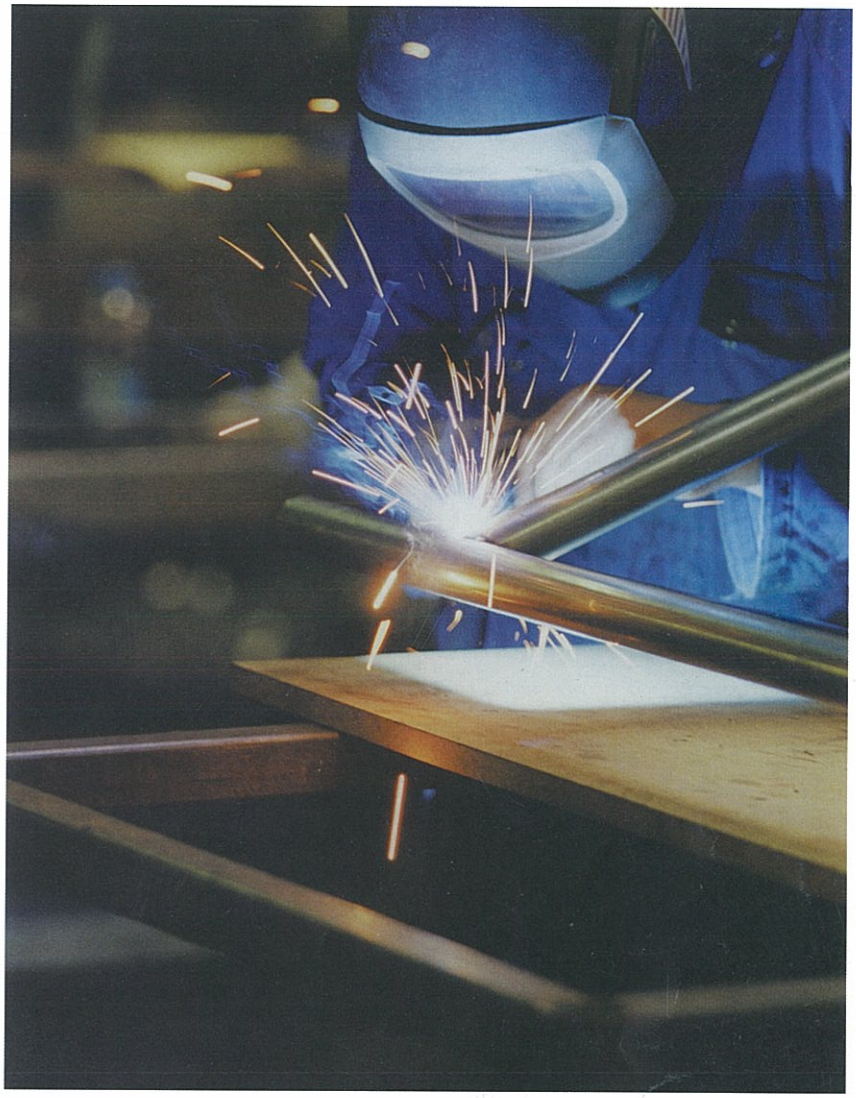


Fig. 4.19. Starting to fully weld the frame. Remember to weld alternate sides to minimise distortion. Spot the deliberate mistake – the welder should be wearing thick gloves! (Steve Williams)

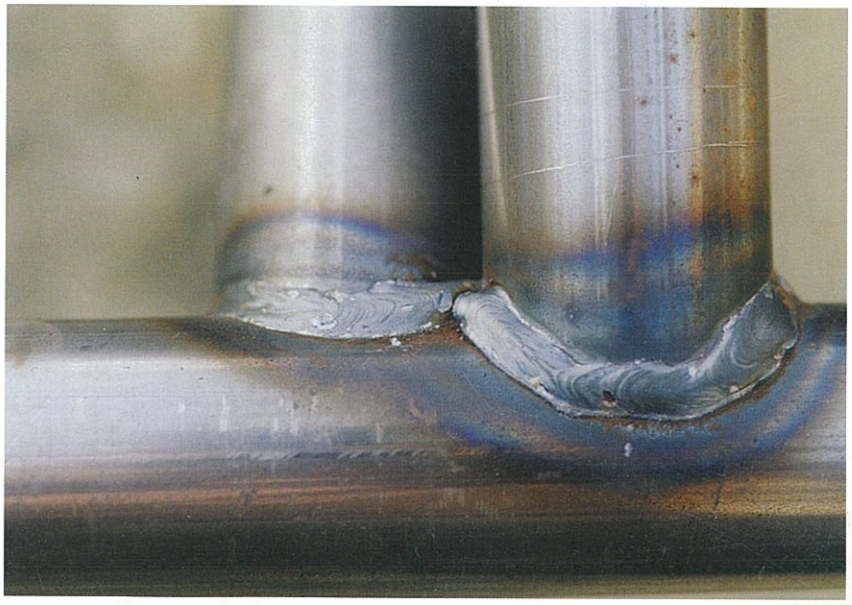
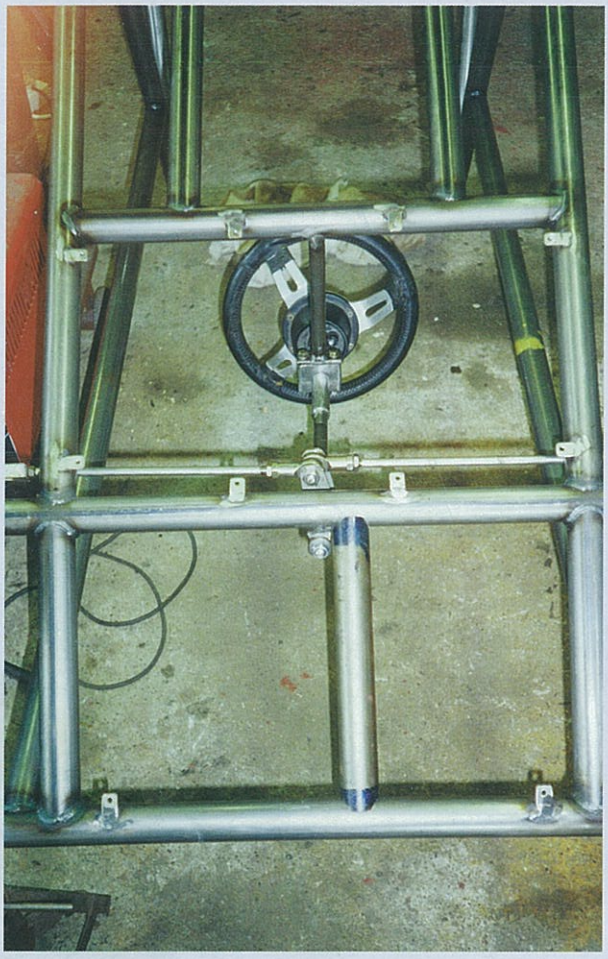


Fig. 4.20. Fully welded frame tube joints. (Steve Williams)

Alternative solutions

A view of the underside of the Buggy, showing the floor mounting lugs welded to the lower frame tubes. (Derek Manders)



Full-length floor

The floor could be made full-length, but if you decide to do this on a Buggy with an air-cooled engine, be careful not to shroud the engine too much, as air-cooled engines need good airflow.

Aluminium floor

Although steel sheet is the best material to use for the floor, aluminium could be used. However, bear in mind that aluminium provides poor protection against flying stones, as it is easily punctured and damaged.

Detachable floor

If the floor is detachable, it is easier to clean the Buggy frame, and any dirt trapped between the edges of the frame and the floor can be removed. One easy method of making the floor detachable is to weld a series of lugs to the bottom of the frame lower tubes. The lugs can be tapped (with, for instance, a 6mm thread) to allow the floor fixing bolts to screw into them.

One of the screws securing the floor to the mounting lugs on the frame. (Steve Williams)