

The Carriage Still

An
Advanced Fractionating Still
for Amateurs



by
John Stone

Foreword

After 17 years of designing small reflux stills for use by amateurs in the home, making major changes here, cosmetic changes there, sometimes doing nothing more than making a change for the sake of change, we feel that it's time to freeze the design and make it available immediately. Amateur distillers around the world can then start to build one for themselves and enjoy the fruits of their labour.

The Carriage Still combines all the best features of the many designs developed over the years and should satisfy the needs of the most fastidious connoisseurs of high quality spirits.

The Carriage Still

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The Carriage Still

An advanced fractionating still for amateurs

INTRODUCTION

The previous books in this series (1,2,3,4) have described the construction of several different versions of a highly efficient fractionating still for amateur use, but in writing this text we have had to assume that you have not read them. Consequently, we have included some of the same material here in order to make the present book self-sufficient. What we have omitted is the lengthy discussion of distilling theory, this book devoting much more space to construction details and practical matters. The diagrams are very much larger and more numerous because it is assumed that you may actually wish to build a still and not just read about it. It also concentrates on a single design using a glass column, embodying all the best features of the several designs we have developed over the years.

The book provides sufficient detail for the average handyman, possibly with a little help from a machinist friend if you don't have the equipment and expertise yourself, to build a still with superlative performance and elegant appearance. It is capable of turning out the purest alcohol in the world, an alcohol which any scientist in a university laboratory, or any commercial distiller, would be proud to produce. And it is capable of doing so very cheaply, e.g. vodka at \$1 per litre. Using exactly the same still, but modifying the procedures somewhat, it can also be used for producing flavoured alcoholic beverages such as whiskies, rum, brandies, schnapps, etc.

So herewith the book which we have dubbed "The Carriage Still", so-called because it embodies all those features which the "Carriage Trade" would demand. The "Carriage Trade" is a name coined in the Victorian era to describe those snooty people who could afford to travel in their own carriages instead of walking! In the present context it describes those people who demand nothing but the best, a still which is capable of producing the ultra-pure alcohol required for vodka or, by shifting gears, used as a whisky, brandy or rum still.

TYPES OF STILLS

There is nothing very new about stills and distilling, it has been going on for centuries. In terms of equipment you can go to any scientific supply house and they will gladly sell you a variety of glass stills which highly qualified scientists have developed, used and written about. At the commercial level, stills can be found in dozens of tiny villages in Scotland churning out their particular brand of malt whisky. The same holds true for rum distilleries which will be found in most sugar-producing regions like the Caribbean. Or the brandy distilleries of France, the rye distilleries of Canada, the vodka distilleries of Poland or the bourbon distilleries of the United States. Go and visit them. Kick the tires. Talk to the staff. Satisfy yourselves that there are real stills out there, stills where the problems have been solved, stills which have been working for years and producing the various spirits which discriminating souls are buying and drinking.

So is it necessary for us to start all over again and re-invent the wheel. What's the problem? The problem is that none of these stills is exactly right for the amateur. A commercial still 4 metres in diameter and 40 metres high will not fit conveniently into the average kitchen. A small glass still from a supplier of scientific apparatus might require you to mortgage your house to pay for it, and would barely produce enough ambrosia to stick in your eye. Another problem is that, because amateur distilling is illegal in most countries, there are no popular texts on the subject to be found in bookstores. It is only with the advent of the Internet that we have been able to talk freely to one another about this harmless hobby. A word of caution, however. The dearth of information provides a fertile breeding ground for all sorts of crackpot ideas, so it is important for you to realize that, if you wish to build a still yourself, it is essential to stay with established principles and not wander off into cloud-cuckoo land. Change the hardware by all means, but not the principles.

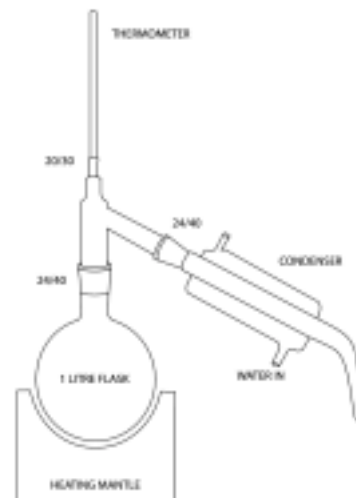
As an example of cloud-cuckoo land, we know of one would-be distiller who tried to make a glass column out of jam jars. He cut the tops and bottoms off, ground them flat and then tried to stick them together. Naturally, the "column" leaked like a sieve so for his next attempt he tried to use a fluorescent light bulb. It shattered as soon as he tried to work it. The moral of this story is that you should save your inventiveness for something that really needs inventing and not waste your time trying to make a silk purse out of a sow's ear. Move ahead, not back. There are lots of opportunities for you to display your ingenuity in the field of small-scale distilling and later in the book we'll suggest a few problems for you to get your teeth into.

Pot stills. There are only two essential elements for a still: a) a boiler, and b) a vapour-condensing system. In the diagrams which follow we start where alchemists must have started way back in the middle-ages, or perhaps it was the Chinese or the ancient Egyptians several millennia before that who started playing around with distillation. One supposes they started with the alembic, shown in Figure 1.

Figure 1 ALEMBIC



Figure 2 SIMPLE LABORATORY POT-STALL



The alembic. Using an alembic (Fig. 1) the alchemist would add the liquid to be distilled or the solid to be sublimed, heat it with a flame, and have the vapours condense back to liquid or solid in the neck. A long neck with a cold, damp cloth wrapped around it would have helped. This is the most elementary form of pot still, or retort as it's sometimes called, and as with all pot stills the principle involved is this: when you boil a liquid containing two or more components, alcohol and water for example, the vapour is somewhat richer in the more volatile component (alcohol in this case) than the liquid. So when the vapour is condensed back to liquid, this liquid has a higher alcohol concentration than the mother liquid from which it sprang.

Laboratory pot still. A modern version of the alembic is shown in Fig. 2. The refinements are i) the flask and the condenser are separate and joined together by ground-glass joints for easy filling, emptying and cleaning, ii) the condenser is cooled by means of cold water running through a surrounding jacket on the downstream side, and iii) a thermometer is provided for measuring vapour temperature. Otherwise, there hasn't been much change in the last few thousand years. This type of still would be used for simple distillations such as the production of distilled water or for steam-distilling botanicals. With a few modifications it could also be used for producing certain types of distilled spirits.

A pot still such as shown in Fig. 2. may be suitable for a two-component mixture but is less suitable, or quite unsuitable, for a multi-component system. Thus, if you had dirty water, or hard water, a pot still would do a good job of producing distilled water, leaving the impurities behind. No problem. But the fermentation of sugar, or grape juice, or molasses, or hydrolysed starch produces hundreds of different organic compounds in addition to ethyl alcohol, and this is a different kettle of fish entirely (if you'll excuse the mixed metaphor). If you use a pot still on

such a mixture you'll get a very crude and uncontrolled separation of the components of the mixture, undoubtedly retaining some very unpleasant-tasting ingredients. The product is known as "moonshine", and although some people profess to like moonshine, or can grow to like it, or will tolerate it because it's cheap, centuries of experimentation have shown that most people prefer to have at least some of the more noxious components removed. Not all, but some. Not many people enjoy the taste of methanol or the fusel oils for example. So, over the years, people have found ways and means to remove some of the worst material using a pot still and leave behind something quite palatable, e.g. a scotch whisky.

Fractionating stills. What we need instead of a pot still is a still with a performance more under our control, a still which is capable of selectively removing certain compounds in the fermentation brew ("beer" or "mash" or whatever you prefer to call it) while retaining certain others. Fortunately, such a still is available and is known as a fractionating or reflux still. A small glass laboratory model using a **Vigreux** column is shown in Figure 3. while a larger one suitable for amateur use, based on our own design and made of glass by a professional glassblower, is shown in Figure 4.

These two stills will be used to illustrate the principles of fractional distillation, so before we get into a discussion of principles take a good look at Figs 3 and 4 and observe the following: Firstly, there is a long tube or column mounted above the boiler. Secondly, the vapour rising from the boiler does not do a U-turn and flow back down into a condenser where it is collected as liquid. It continues upwards into a condenser where the vapour is condensed to liquid. The liquid then runs back down through a device called the "stillhead" where it is divided into two separate streams, one stream (representing about 90% of the condensate) continuing on down to the boiler while the other stream (10%) is directed to the outside world by means of a valve or stopcock.

Such a procedure will seem strange to those of you who have only been involved with simple pot stills where you collect all the vapour. Return 90% of the condensed vapour to the boiler! Whatever next! However, we shall be referring to this over and over again in the following pages, so will not elaborate upon it at this juncture.

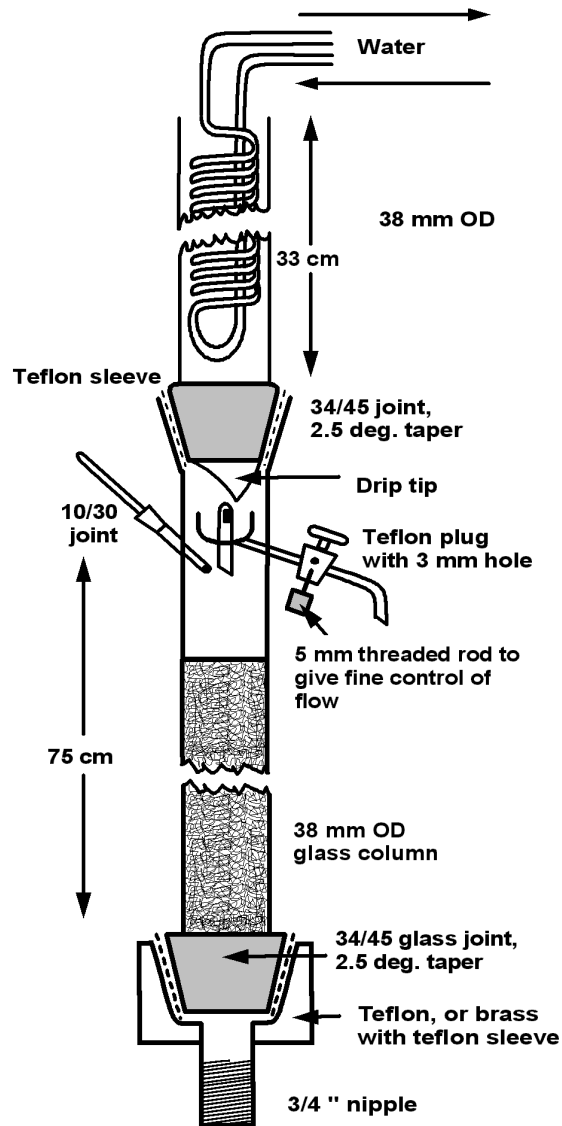
Figure 3. Laboratory fractionating still (Vigreux)



Figure 4 (a) All-glass amateur reflux still (Stone)



Figure 4 (b) All-glass amateur reflux still (Stone)



THE PRINCIPLES OF DISTILLATION

The principles of fractional distillation are the same whether one is dealing with a small glass laboratory still such as shown in Fig. 3 (Vigreux) or a mighty commercial stainless steel tower 4 meters across and 40 meters high. The principles were discussed in the previous book in this series, but it is necessary to repeat some of the same discussion here. Shamelessly, therefore, we quote almost word-for-word from “Making Gin & Vodka ---A Professional Guide for Amateur Distillers” (4).

As a result of fermenting any natural source of sugar, be it grapes, molasses, potatoes, milk (lactose) or whatever, a whole host of organic compounds will be produced. Among the more important are those listed in the table below. Please note the differences in boiling point.

Compound	Boiling point, °C.
Acetone	56.5
Methanol	64.7
Ethyl acetate	77.1
Ethyl alcohol (96%), the azeotrope	78.1
Ethyl alcohol (100%)	78.4
Propyl alcohol	97.2
Water	100.0
Butyl alcohol	117.5
Amyl alcohol	137.8
Furfural	161.0

Chemicals with different boiling points such as those in the table above have different vapour pressures, the most volatile at the top of the table with the lowest boiling point having the highest vapour pressure at any particular temperature. A liquid boils when its temperature is raised to the point where its vapour pressure equals atmospheric pressure. Thus, if the room temperature is 25° C. and you have a bottle of acetone, you only have to raise its temperature 31.5° C. and it will boil. Or you can make it boil at room temperature by reducing the pressure, i.e. by applying a vacuum.

It is now necessary to dispose of a myth concerning distillation which is quite prevalent, so prevalent in fact that it is the basis of several small-scale stills being offered for sale. The myth goes like this: If you have a mixture of (say) three liquids with different boiling points, e.g. methanol (64.7 °C.), ethanol (78.4 °C.) and water (100 °C.) it is believed that, if you raise the temperature to 64.7 °C., and hold it there the methanol will boil off. Then, if you raise the temperature to 78.4 °C. the ethanol will boil off. This is completely untrue and illustrates the misinformation being disseminated by well-meaning but ill-informed hobbyists. It might be approximately true for liquids which do not mix with one another, such as gasoline and water, but is totally untrue for liquids which are completely miscible with one another such as those in

the above table. Being miscible they associate with one another at the molecular level and no longer act independently as individuals.

Having expunged this fallacy from our minds, and hopefully from all future writings on this subject, let's take a look at what really happens. When a mixture of liquids of different boiling points is brought to the boil, the vapour contains ALL the compounds which are in the liquid, but the vapour has become richer in the more volatile components. This can be proved by condensing the vapour to liquid and analyzing it. It is the basis of all distillations --- the vapour is richer than the liquid in volatile constituents.

Simple distillation – the pot still

First let's take a look at the simplest situation --- the events taking place in a pot still such as that shown in Fig. 2 when beer is distilled. The vapour is richer than the liquid in the most volatile constituents, i.e. the ones with the lowest boiling points such as acetone and methanol in the above table. When they distil over they are referred to as the "heads". There is no clear-cut separation of the various compounds so the heads will still be coming over when the ethanol starts to appear. Similarly, before all the ethanol has distilled over, the "tails" will begin to appear in the distillate. These tails are the compounds at the lower end of the above table, i.e. those with the highest boiling points such as propyl, butyl and amyl alcohols. These alcohols are known collectively as "fusel oils" and, like methanol and some of the other compounds, are quite poisonous.

In such a system there may be a tiny fraction in the middle which is pure ethyl alcohol but most of it will be contaminated with either heads or tails. One could discard the first heads and the last tails and re-distil the tiny middle fraction, repeating this process over and over again until the last of the impurities had been wrung out of the ethanol. Unfortunately, apart from being very time consuming, the loss of ethanol on repeated re-distillation would be such that the final yield of pure alcohol would be virtually zero. Fortunately, there is a very elegant procedure known as fractional distillation which, in a single operation, has the same effect as carrying out hundreds or even thousands of re-distillations one after another, and without losing anything while doing so.

Fractional distillation.

When reading this section please refer back to Figures 3 and 4. Two things distinguish fractional distillation from simple or pot distillation. One is the equipment used while the other is the procedure. Take the equipment question first. A fractionating still has a tall column mounted above the boiler, and this column is packed with pieces of glass, or ceramic, or metal with the following characteristics:

- a) The packing should be inert and not react in any way with the liquid being purified. Glass, ceramics and stainless steel are ideal in this regard.

- b) The individual elements of the packing should be small in order to provide a large surface area. They should also be of such a shape that they do not pack tightly together, thereby leaving plenty of free space for vapour to rise up against a descending flow of liquid.
- c) They should pack uniformly in order to avoid channelling.

One of the best examples of a fractionating column for illustrating the above, even though it doesn't use loose packing, was shown in Figure 3 --- the Vigreux column. Being made of glass one can see exactly what is going on inside and it's rather pleasant to watch in operation.

Such a column is only used in small laboratory distillations. A typical column is 600 mm high and 25 mm in diameter, and has a series of indentations made at intervals up the length of the column to provide the surfaces where liquid-vapour interchanges can take place. The indentations are made with a pointed graphite probe while the glass is softened in a flame. At each level (and there are 13 levels in a 600 mm column), eight indentations are made around the points of the compass, four of them at N,S,E and W being horizontal while in between another four indentations point down at a 45° angle. These indentations, and there are $13 \times 8 = 104$ of them, take the place of the packing which will be discussed later.

So now we come to the procedures involved in fractional distillation, again illustrated with the Vigreux column. In a simple distillation, as with the pot still in Fig. 2, all the vapour rising out of the boiler is condensed and collected. In fractional distillation the condenser is at the highest point in the system and the condensed vapour (liquid) drops back down through a "splitter" known as the "still-head". The function of the still-head is to divide the condensed vapour into two separate streams, one of which is allowed to continue on down towards the boiler while the other is directed to the outside world via a sidearm and stopcock. In the column, therefore, rising vapour encounters falling liquid in a counter-current flow. Here's where the extra surfaces provided by the indentations come into play.

The liquefied vapour dropping down from the condenser has had its latent heat removed by the cold surfaces in the condenser (that's why it changed from vapour to liquid), and when this liquid cascades down the column, splashing from one set of glass indentations to the next set below, it meets a stream of vapour, still containing its latent heat, coming up. On each surface the vapour gives up its latent heat to the liquid, which immediately vapourizes. Having given up its latent heat the vapour condenses. So the liquid vaporizes and the vapour liquidizes (condenses). Each exchange between liquid and vapour on one of the tiny glass lobes is equivalent to a mini-pot-still distillation, the vapour becoming richer in the more volatile components of the mixture while the liquid becomes depleted in these volatile components. The vapour is carried up while the liquid falls down towards the boiler. At each interface down the column (the indentations in a Vigreux column) the exchange is repeated, so the rising vapour emerging from the boiler becomes richer and richer in volatile components as it goes up the column while the falling liquid becomes richer and richer in the least volatile components. In a Vigreux column with 13 sets of indentations at various levels we have the equivalent of 13 re-

distillations. As we shall see later, with a long enough column filled with an efficient packing we can achieve the equivalent of hundreds of re-distillations.

In Figure 4 is shown a glass reflux still designed by us and made by a professional glassblower. It is larger than the Vigreux still and uses stainless steel filaments as packing rather than glass indentations. Its capacity is such that it can produce 4 to 5 litres of 96% ethyl alcohol (the azeotrope) in 36 hours. Its operation is best followed with the aid of the diagram provided in Fig. 4 (b). Vapour rising from the boiler is condensed by the cooling coil and drips back down into the receiving cup of the still-head. This cup has a bottom drain leading to the outside world and an overflow which comes into play when the drain is closed with a stopcock and the collection cup fills up. By suitable adjustment of the stopcock, therefore, the flow of liquid falling down through the packing towards the boiler can be adjusted from zero to 100%. With the stopcock closed all the condensed vapour returns to the boiler and this situation is referred to as "total reflux". If the stopcock is cracked open a little so that, say, 10% of the total reflux flows out to the outside world, this situation is referred to as a reflux ratio of 10:1. The other 90% of reflux which is not drawn off flows back down the column to continue the mini-distillations and purification process on all the surfaces down the column. If we drew off all the reflux so that there was none left to flow back down the column, there would be no series of mini-distillations, no purification, and we'd have what amounts to a pot still.

It is tempting at this point to launch straight into a description of the carriage still, but before doing so a few words will be said about health, safety and the law. You will take more pleasure in building a still if you feel quite sure that you won't be poisoning yourself, blowing yourself up, or being dragged off to the slammer.

HEALTH & SAFETY

The three major concerns of people who might be interested in setting up a still at home are 1) the question of legality, 2) the possibility of getting poisoned, specifically of going blind, and 3) the danger of blowing oneself up. These are serious concerns, and people take them very seriously. In Appendix V the legality question is dealt with at length, and if you haven't read it before we invite you to do so when you have a few minutes spare, but for the moment the emphasis will be on health and safety.

Poisoning oneself.

The belief that there is some inherent danger in distilling one's own spirits is widespread and is reinforced whenever the news media report that a number of people have been taken ill, or even died, as a result of drinking homemade spirits. People associate "homemade spirits" with distillation, with moon-shining, but in fact there is no danger whatsoever in drinking home distilled spirits, or even moonshine properly made. The danger lies in buying liquor from a bootlegger because in order to increase his profits he may top up his moonshine with rubbing alcohol (methanol), or stove oil, or antifreeze or paint remover or any other pungent liquid he can lay his hands on. Naturally such a cocktail is poisonous, but don't be misled into thinking that the toxicity is due to simple ignorance or lack of care on the part of the backwoods distiller. It's not. It's due to these gentlemen adulterating their booze and fobbing it off on an unsuspecting public.

Our recommendation is that you never buy moonshine made in an illegal and unsupervised still, possibly adulterated with unknown chemicals. Make your own if it's legal to do so, in which case there will be no danger whatsoever to your health. This is particularly true of fractional distillation, where you have removed ALL the impurities, but also for simple distillation where you have removed at least some of them. Your equipment will be made of glass, stainless steel or copper, and if made from copper the various parts will be joined with lead-free solder. It would be similar to a Scotch whisky distillery where copper stills have been used for centuries. As for dangers in the distilling operation itself, let us follow this through. Sugar is fermented to alcohol using bakers' yeast to make a crude "beer". No danger so far, right? The beer is boiled and the vapours collected. The first liquid to come over will contain some methanol (poisonous), acetone and small amounts of other substances which were in the original beer, the so-called congeners. They smell like paint remover and will be discarded. Then comes the potable alcohol which has no smell and is collected for use. Finally there arrive the fusel oils with a somewhat unpleasant odour so they, too, are discarded. Remember, the distillation has not created anything, it has simply separated out the noxious substances from the beer --- the heads and tails.

So, to poison oneself, it would be necessary to remove the congeners from the beer by distillation, pour the purified alcohol down the drain and then, ignoring the pungent smell and sickening taste, drink the paint remover. This is about as likely as plucking a chicken, throwing away the meat and eating the feathers. It strains credulity to put it mildly.

Headaches and hangovers

Headaches and hangovers are well-known consequences of over-indulgence in alcohol, but what is far less well known is that these unpleasant side-effects are largely due to the impurities, the congeners, and much less to the alcohol *per se*.

This interesting fact will be confirmed by many people who habitually drink gin or vodka rather than pot-distilled spirits such as rye, bourbon, scotch, rum or even wine and beer. More objective proof that the congeners and not the alcohol are the bad actors can be found in the scientific literature. Numerous studies have been made and all investigators find the same thing, i.e. that the symptoms of hangover --- headache, halitosis, gastric irritation, fatigue and dizziness --- were far more severe when the same amount of alcohol was consumed in the form of whisky than in the form of vodka. When you think about it, this is hardly surprising considering the poisonous nature of some congeners.

As an example of such studies, in one clinical investigation 33 men and 35 women were each given 2 ounces of either whisky or vodka on separate occasions. The incidence of after-effects in the group following a single drink of 2 ounces of whisky was halitosis 27%, gastric irritation 25%, headache 9%, dizziness 7% and fatigue 6%. These symptoms persisted during the following day. After the same amount of vodka, temporary headache and gastric irritation were observed in only 2% of the subjects while there were no complaints of halitosis, dizziness or fatigue in any of the cases. It should be noted that all the subjects in this trial were light social drinkers.

The effects described above were produced by a commercial whisky in which the congeners occurred to the extent of about 3%. As part of the study the congeners were separated from the whisky and given to the subjects in the absence of alcohol. The effect was the same as when the whisky itself was imbibed, proving that the congeners and not the alcohol were responsible for the adverse reactions. The chief culprit among the congeners was considered to be one of the fusel oils --- amyl alcohol --- and not methanol as might have been expected.

These results are not really definitive --- for one thing the size of the sample was rather small --- but even without such a trial it is not difficult to believe that drinking such things as methanol and fusel oils, even in small amounts, will be bad for you. If it were a different poison, e.g. arsenic, it would not be surprising if a 3% solution in alcohol, or even in water, gave you an upset tummy. 3% is not a trivial amount when one considers that nowadays the authorities are concerned about parts per billion of contaminants in foodstuffs.

One of the conclusions to be drawn from such studies is that whisky production should be handled carefully by amateurs. As mentioned in earlier sections, pot-distilled spirits involve the retention of some of the congeners in order to give taste to the whisky, but some of these taste-providing congeners are poisonous so don't overdo it. It would be wiser, perhaps, and certainly easier, to remove all the impurities by fractional distillation to give a pure alcohol and then add a flavouring agent. The physiological effect of an alcoholic drink, the 'buzz', is due solely to the alcohol, and everything else is merely moonlight and roses!

A final comment concerns the question of alcohol concentration in beverages. In beer the concentration is about 5%, in wine it is 8 to 13%, while in distilled spirits it is usually 40%. Only a moment's thought is required to appreciate that the concentration of alcohol in a drink is irrelevant, it is the amount consumed which is the determining factor in determining whether or not someone becomes inebriated. Drinking a bottle of beer is not less harmful than a 1½-oz. drink of 40% scotch just because it is weaker. They both contain identical amount of the same alcohol, i.e. 17 ml. Adding tonic water to a shot of gin dilutes it from 40% to maybe 6% but this has not rendered the gin less intoxicating --- the amount of alcohol has remained unchanged.

This is all so obvious that it may seem a little absurd to even mention it but, in most countries, the concept appears to be somewhat too difficult for the official mind to grasp. This is shown by the fact that governments put a much higher tax per unit of alcohol on distilled spirits than on beer and wine. The reason for doing this, it is claimed (somewhat piously) is to discourage people from drinking something which could be harmful to their health. A more likely reason is that they see it as an opportunity to increase tax revenue. If a government wished to base their tax grab on a rational argument they should start by basing it on alcohol amount (so much per unit of alcohol) instead of on alcohol concentration. And then, if health were the primary consideration as they claim, an additional tax would be levied based on the amount of poison (congener) present. Vodka would then attract the lowest tax of all and we would all live happily ever after!

A final note for environmentalists and watchdog groups on health matters: Is it not time to demand that governments require all manufacturers of alcoholic beverages to list the composition on the label? This would enable us to choose the ones with the lowest levels of toxic ingredients. They do it for food so why not for drink, particularly for drink which is *known* to contain several poisons.

Fire and explosions.

This may sound a bit melodramatic but when you are dealing with a procedure for the first time, and know that alcohol is inflammable, you may wonder. Let's take the explosion issue first. At no time, from beginning to end, is there any pressure in the equipment used for distillation. It is always open to the atmosphere. Fully open. Completely open. You will see that this is so when you look at the equipment diagrams later on and read the description of the procedures involved. So don't worry about it --- an explosion is virtually impossible.

As far as fire is concerned you are dealing with an aqueous solution of alcohol which is non-inflammable right up to the time you collect the pure 96% alcohol dripping from the draw-off valve. This is inflammable, but most people will be using an electrically heated boiler so there is no open flame. Secondly, in the remote possibility that a fire occurred, alcohol fires can be instantly doused with water because alcohol and water are miscible. For this reason it is much safer than gasoline, and in the fuel alcohol industry this fact is always quoted as one of the benefits associated with ethanol when it is used alone as a fuel --- in Brazil for example.

THE CARRIAGE STILL

The evolution of the still

The carriage still evolved over a number of years, starting with an offset arrangement of column and condenser made of copper which we whimsically referred to as the “Mexican Cactus” because it had a bent arm and looked rather like that well-known feature of the Mexican landscape --- the sequaro. It has worked extremely well since 1993 and is highly recommended from a practical standpoint, even if aesthetically it leaves something to be desired. From the “Mexican Cactus” we progressed to the “Hatstand” model, shown in Figure 5 below and made of copper. Internally the design is identical to the design shown in Fig. 4--- a vertical tube (copper in this case) with a cooling coil at the top, a still-head for splitting the condensate into two streams, and a column packed with stainless steel filaments.

Figure 5. Copper reflux still. Used for research



Let's take a look at Fig. 5. This still is made from 1 ¼" copper tubing and the innards (which naturally you can't see) can be understood by looking at the diagram in Fig. 4, the innards of which you can see. A copper cooling coil at the top condenses vapour to liquid. The liquid falls into a collection cup with an outlet at the bottom and an overflow leading down to the top of the packing. A needle valve controls the ratio of drawn-off liquid to reflux liquid. It works perfectly, doing an excellent job of producing pure alcohol, and being made of copper can be easily constructed by any handyman with a few lengths of copper tubing and a propane torch. And it is very rugged. But it does suffer from a single disadvantage ---- you can't see inside it. Seeing inside is not really necessary, not necessary at all in fact, but it adds a lot to the pleasure derived from distilling if you can see something going on. Otherwise the still is simply an inert lump of uninteresting metal. Boring. But if you can see sparkling liquid dripping inside, the whole operation comes alive.

This was when we changed to glass, having the glass still shown in Fig. 4. made for us by a professional glassblower. And because of its appearance we enjoyed using it, and still do. This, surely, is what a hobby is all about --- the aesthetic and material pleasures which the hobby can bring to you. And also to your friends, who probably know little about distilling but will happily watch the alcohol dripping in your still as you explain to them the mysteries of reflux ratios, etc. And when you hand them a shot glass of your very own vodka they'll sip it appreciatively, happy in the knowledge that they've seen the

purification process with their own eyes. They trust the liquid dripping from a glass still much more than they would if it had simply appeared from inside a length of copper pipe.

When changing to glass the copper still shown in Figure 5 was not wasted. It was converted into a research still. You will notice a number of white Teflon plugs in the upper section of the column, each plug having a small hole where a digital thermometer probe can be inserted. A small pin closes the holes of those plugs not in use. With this set-up we can study the effect of different reflux ratios and different packings on the temperature profile within the column.

The all-glass still shown in Fig. 4 is a pleasure to use but unfortunately for general use it suffers from two disadvantages (there's always some disadvantage isn't there?). The first is that it involves some fairly sophisticated glassblowing, so you cannot make it yourself and you will be hard-pressed to find someone who will make it for you. Having found such a person you will find that he'll charge several hundred dollars for it. Maybe it's worth it. After all, we went to the trouble and expense so why not you? But then there's a second problem. Glass is somewhat fragile and you have to handle the still with kid gloves. Then, if you happen to break something, it's back to the glassblower for expensive repairs.

Which brings us to the carriage still. The goal we set for ourselves was that it should be made of glass (or mostly made of glass), not require the services of a glassblower, be reasonably priced and be rugged. These seemingly conflicting requirements can be satisfied, or almost so, by using a compression fitting to seal plain glass tubing to metal. We'll explain this with the aid of diagrams and photographs as we go along but will keep you in suspense for a little longer while we start at the beginning and take everything in logical order, starting with the boiler.

The Carriage Still

The boiler

When it comes to amateur distilling there seems to be a burning desire on the part of the handyman to improvise a boiler out of some odd vessel which happens to be available, and no-one should be surprised to learn that everything from pressure cookers to beer kegs to milk churns to vacuum cleaner tanks have been adapted by ingenious do-it-yourself types for this purpose. However, we strongly recommend that you save yourselves a lot of time, trouble and expense by using an ordinary domestic hot water heater. In N. America these are available in all sizes from 9 litres up to several hundred litres, and are ideally suited for acting as the boiler in all amateur distillation systems. They are rugged, glass lined, already have an immersion heater installed, they are insulated, they have pipe fittings in all the right places, and are housed in attractive white-enamel steel housings. What more could you wish for? If you had drawn up the specifications yourself for the ideal boiler required for a still it would not be very different from a hot water heater. In N. America they cost around \$140 in all sizes up to 100 litres.

A few simple modifications to the hot water heater are required. Firstly, remove or bypass the thermostat. We need the contents of the boiler to boil, so a thermostat which switched off at a temperature of, say, 75° C. would obviously defeat our purpose. Removing the thermostat may seem dangerous, and it would be if we had a closed system, but the system is

open to the atmosphere at all times so there can be no pressure build-up. It is just like a tea-kettle. For this reason you also can dispose of a pressure-relief valve if one is installed because the pressure inside the boiler is never above atmospheric.

The location of pipe fittings on water heaters vary from manufacturer to manufacturer, but whichever one you choose you'll find a fitting at the bottom (the cold water inlet) and several at the top. If you need another $\frac{3}{4}$ " pipe fitting at the top you may find one by removing the sheet metal cover and fiberglass insulation from the top of the housing. This is where in some models the magnesium rod used as an anti-corrosion device is installed. It can be removed because it is not essential in our application and the $\frac{3}{4}$ -inch female pipe fitting may be useful to you for mounting the column.

The lower connection, the cold water inlet when the tank is used for domestic hot water production, will become the inlet for beer from the fermenter and also the drain for the exhausted beer (the stillage) after stripping. Fit this connection with a $\frac{3}{4}$ " ball valve and screw into it an adapter for connecting a short length of rubber garden hose. Use a ball valve at the drain, and not an ordinary faucet, because the yeast in beer forms sticky lumps when boiled and there should be a wide opening for the yeast clumps to exit to drain.

As far as size is concerned, either a 25 litre or a 50 litre hot water heater is convenient. We use the 25 litre model but a colleague uses the 50 litre size. It's a toss-up.

Power supply.

The packed column which will be mounted above the boiler (see later) has only a limited capacity to allow vapours to rise up through the packing against the downward flow of condensed liquid so the boil-up rate must not be too great or the column will choke (flood). If you use a 38 mm o.d. glass column and the stainless steel filamentous packing which we recommend a bit later on, you can probably use 1500 watts. Try it. However, with packing which leaves much less open space, e.g. Raschig rings, you may experience choking, in which case you'll need to find a way to reduce the wattage somewhat. For N. American readers a simple method would be to buy a 3,000 watt, 240 volt heating element and use it on 120 v. This will give you 750 watts. We use 750 watts rather than 1,500 watts because the slower distillation is steadier and more convenient for carrying out a distillation overnight. Also, the cooling coil can cope more easily with the smaller quantity of vapour. For readers who live outside N. America an immersion heater of 1,000 watts may be available and could suit you very well.

Incidentally, you do not need to measure either the temperature or the pressure in the boiler ---- the pressure is atmospheric and the temperature is the boiling point of beer, e.g about 100° C.

The column

This is going to be made of 38 mm o.d. (34 mm i.d.) Pyrex glass tubing, but where do you get glass tubing? We had the advantage of a university connection so dropped in to the storeroom of the chemistry department and bought a 4 ft length over the counter for \$12. Maybe you can do the same. Glass tubing is made in all sizes from tiny capillary tubes to vary large diameters, and with different wall thicknesses, but you'll have to search around a bit in your location to find a supplier. Look in the yellow pages under "Scientific Supplies" because such people certainly stock it. Maybe a supplier of sheet glass can get hold of tubing for you. A university, college or industrial chemistry department will undoubtedly have some and you can probably sweet-talk them into selling you a single 4 ft length (this is the standard length in N. America and should cost from \$12 to \$20 for 38 mm diameter.) You will also find numerous suppliers of Pyrex glass tubing on the Internet, but their price for a single 4 ft length might be a bit high.

The rule of thumb is that the height of a column should be at least 15x its inside diameter, which would mean a column height of at least 510 mm for 34 mm i.d. tubing, but why not be generous and add a few more centimetres. The higher the column the better (within reason), because it provides a larger number of solid/vapour interfaces up the length of the column and therefore more re-distillations. The 800 mm we suggest is convenient but you won't wish to go much over this or you will hit the ceiling! So cut your 4 ft (1219 mm) length of glass tubing into two parts --- 800 and 400 mm. The longer piece will be the column while the shorter piece will form the condenser. Use a masonry blade on your table saw and take it easy, not allowing the glass to overheat. The two cut ends must be fire-polished to avoid chipping, using a propane torch with a broad brush flame to pre-heat several inches of the glass tubing and then a more concentrated flame to bring the cut ends to red heat. A propane/air flame is barely hot enough to melt Pyrex glass so it is much better to use MAPP (methylacetylene propadiene) which gives a flame temperature of 2900° C. Stroke the heat over a large area of the glass tubing and then cool slowly. A glassblower would use an annealing furnace to remove strain within the glass.

The packing.

The packing inside a fractionating column is very important and many articles in the scientific literature are devoted exclusively to this topic. Everyone has his own ideas on what constitutes the ideal packing and the writer is no exception. Unlike scientific texts, however, cost is a consideration here provided performance is not compromised. What is needed are pieces of glass, ceramic or metal which are inert to the liquid being refluxed and which have the following characteristics (mentioned earlier but repeated here):

- a) they should not pack tightly and should be of such a shape that they leave plenty of free space for vapour to rise up against a descending flow of liquid;
- b) they should pack uniformly in order to avoid channeling, and

c) they should have a large surface area and crevices where liquid can be trapped.

Scientific glass columns frequently use short, e.g. 6 mm lengths of 6 mm glass or ceramic tubing called Raschig rings. Ceramic saddles are another popular shape. Glass marbles might be used in large diameter columns but do not have sufficient surface area for a small diameter column such as ours. Also, unlike Raschig rings, they do not have any pockets where liquid can be trapped, so are rather inefficient.

The packing which we recommend has a very domestic origin but is cheap and highly effective. It consists of the scrubbers or scourers used for cleaning pots and pans and found in any supermarket. These are not the fine steel wool pads impregnated with soap but the much coarser scrubbers made from lathe turnings which usually come in a ball. They are available in copper, brass and stainless steel, and the ones to choose are the stainless steel. Several will be required for the column. Commercial packings using the same principle are available (at a price), and are very neat and uniform in surface distribution because the stainless steel filaments are woven into a blanket and the blanket is then rolled into a cylinder to exactly fit the inside of the column. Photographs of both types of packing are shown in Figure 6.

Packing the column is relatively simple. Pull out the balls of tangled filaments into sausage shapes and carefully shove them into the column from both ends with a minimum of compaction. Leave a small space between each unit of packing in order to disrupt any channeling which may have started in the unit above. This type of packing only occupies about 4% of the column volume, leaving 96% open space, appreciably better than Raschig rings. It also has a much larger surface area, so you will find it very effective.

Figure 6. Packing



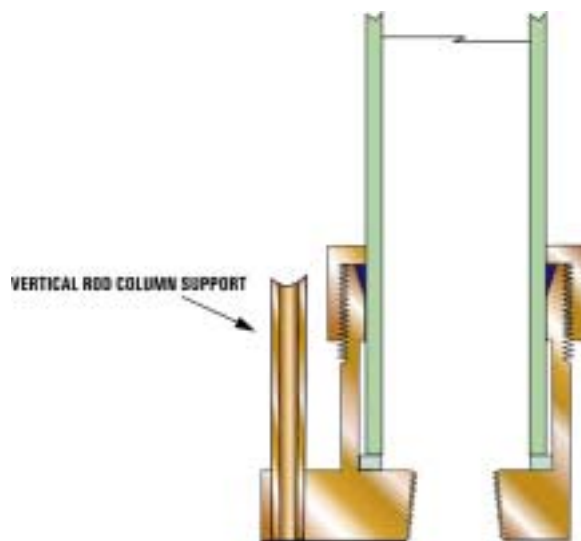
Glass-to-metal seal.

To avoid glassblowing it is necessary to devise a method for sealing straight glass tubing to brass. We may not be able to work with glass but we can certainly work with brass --- turning it on a lathe, soldering it, drilling and tapping holes in it. The answer to the problem proved to be a compression fitting such as the one used (in N. America) for the waste disposal pipe under a sink or laundry tub. Being used in domestic situations it is very cheap. The size of glass tubing which exactly matches the tailpiece under a sink is 38 mm o.d., a standard diameter readily obtained, so this determined the diameter of our distillation column. A good machinist can easily make compression fittings of any size so you are not limited to 38 mm.

Column-to-boiler mount.

An exploded-view photograph is shown in Fig. 7 (a) while a diagram is shown in Fig. 7 (b). A solid brass plug at the base of the adapter is threaded with a $\frac{3}{4}$ " pipe thread to connect to the boiler via a $\frac{3}{4}$ " nipple. The base of the glass column rests on a Teflon cushion as shown in the diagram but is not intended as a seal. The seal between the glass tube and the brass adapter is made by tightening the knurled nut to squeeze the nylon ferule between glass and metal. If you prefer, a Teflon or Viton O-ring will serve the same purpose and be more chemically resistant.

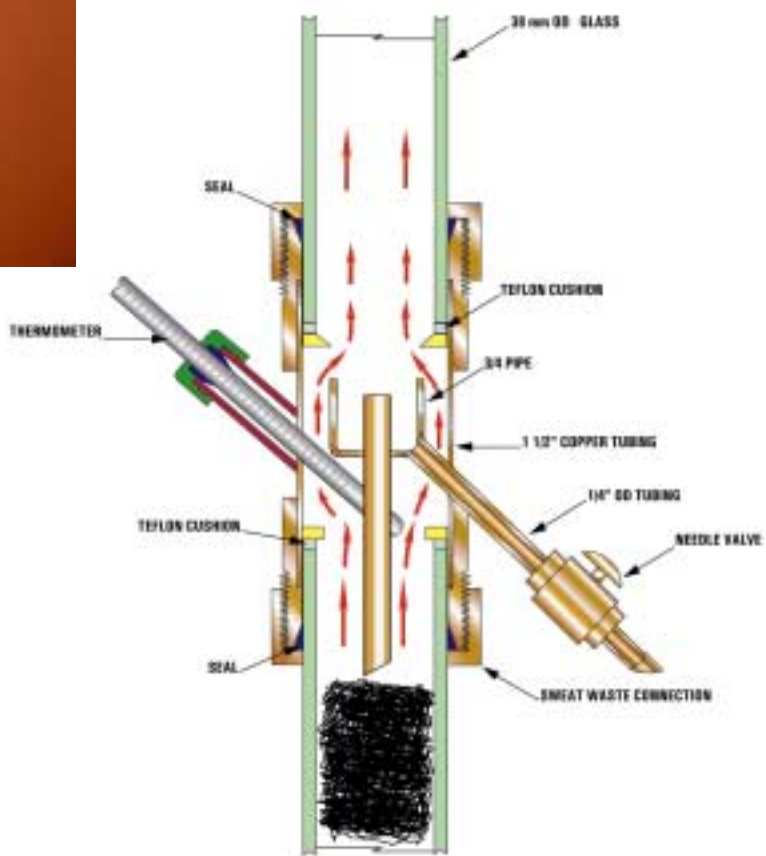
Figures 7 (a) and (b)



Figures 8 (a) and (b) **The still-head.**



At the top of the column is the still-head and a photograph of it is shown in Fig. 8 (a) while a detailed drawing of its internal features is shown in Fig. 8 (b). You will realize, of course, that despite our statements above about transparency and the pleasure of seeing liquids merrily dripping away inside a still-head, this still-head is solid brass and totally opaque. . Sadly, a partial loss of transparency is a sacrifice we had to make in the interests of cost, convenience and ruggedness.



However, all the advantages of transparency are not lost because it's still possible to see condensate dripping from the bottom turns of the cooling coil into the still-head and dropping out of the still-head onto the packing. Pin a diagram on the wall so that your visitors can understand what's going on inside! Our machinist said that he could make a still-head in about an hour if he was all set up and had several to make, so why not talk your friends into constructing their own still and save money through economy of scale!

Features of the still-head are these: a). Two compression fittings are required, one for the top of the column and the other for the bottom of the condenser; b) a shoulder above the collection cup is sized so that any liquid running down the walls of the condenser will still fall into the cup and not continue flowing down the walls. Overflow exits over the top of the downcomer. c) the thermometer, either mercury/glass or digital, is inserted through a small compression fitting as shown, slightly offset to avoid the downcomer. For a glass thermometer a couple of turns of Teflon tape act as the ferule when the nut is tightened down. For the 3 mm probe of a digital thermometer use a small Teflon plug with a hole drilled through it or many turns of Teflon tape. There is no pressure in the apparatus and the seal is excellent.

The collection cup is as shown. A central tube extends down below the point where the thermometer bulb will be located in order to prevent liquid falling on to the bulb of the thermometer. The liquid is cooler than the vapour. It also should extend to the top of the packing so that the dripping liquid condensate can be observed through the glass column.

At the bottom of the cup at one side a draw-off tube about 6 mm in diameter is soldered. It extends through a hole in the side of the still-head where it is soldered in place. A needle valve controls the flow through this tube. On the few occasions when total reflux is required the upper end of the overflow tube can be closed with a small Teflon plug to prevent condensate falling directly through on to the packing. When the valve is wide open (and the overflow tube plugged) all the condensed liquid exits to the outside world, and when it is closed (and the overflow plug removed) the condensate all flows down on to the packing. The volume of liquid flow is quite small, about 50 ml/minute with 750 watts input to the boiler and needs to be under fine control, so use a good quality small needle valve with a fine thread on the stem.

The top of the column slips into the bottom of the still-head and there should be a shoulder inside about 35 mm up to take the weight of the assembly bearing down on the top of the column. There is a small clearance between the glass tubing and the brass housing, and we like to wrap a few turns of Teflon tape around the glass to prevent it rocking.

The 400 mm length of glass tubing for the cooling coil is sealed to the still-head by means of the upper compression fitting. The cooling coil itself is wound from 3/16" copper tubing and will be described later.

If you prefer to buy and install a small compression fitting for the thermometer rather than make one from scratch, proceed as follows:

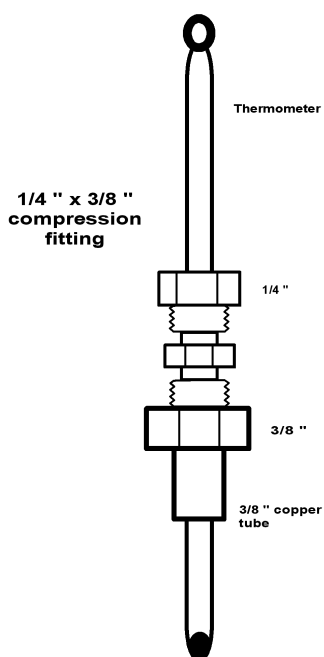
Thermometer adapter. Purchase a 3/8" x 1/4" compression fitting. They only cost \$3 or \$4. There is a shoulder inside these fittings at the mid-point and you will need to drill away this shoulder to let the glass thermometer pass right through. Use a 17/64" bit and drill from the large end, trying to avoid going right through and damaging the seat for the ferule at the 1/4" end. If you use a digital thermometer, which usually has a 1/8-inch probe, the 1/4-inch compression fitting is large enough as is without removing the internal shoulder.

Solder a short length of 3/8" copper tubing to the still-head in the position shown, slightly offsetting it so that the thermometer avoids the downcomer. Condensed vapour must not fall on the thermometer bulb since its temperature is lower than that of the vapour. Use Teflon plumber's tape to make the seal, winding several turns around the thermometer so that when the nut is tightened the Teflon is compressed between the thermometer stem and the brass fitting. There is no pressure in the apparatus and no leakage. The bulb of the thermometer should be close to the mid-point of the column so that it is in the main stream of vapour flow.

Note 1. Some thermometers have stems which are slightly too large in diameter to go through a 17/64" hole. Be careful, therefore, to choose a thermometer which will go through. Or, drill a slightly larger hole.

Note 2. A glass thermometer in such a rigid set-up is very vulnerable to breakage. The slightest touch and! It is prudent, therefore, to remove it while working round the still.

Figure 9. **Thermometer adapter**



The condenser.

The alcoholic vapours rising from the boiler are condensed by means of cold water running through a copper coil (see Fig. 10) inserted into the glass condenser housing sitting above the still-head. To make this coil you will need about 5 metres of 3/16-inch tubing (metric tube sizes unknown) and wind it into a tight coil which will fit inside the glass. Use a length of 3/4" copper tubing as a mandrel and support it vertically by clamping in a vise. Stick one end of the 3/16" tubing down the inside and wind the remainder around the outside. Such small diameter tubing is not always found in plumbing supply stores but you will find it in the automotive section of large hardware stores. It is used as a fuel line.

Figure 10. Cooling coil



Water supply

It is worth mentioning that there is considerable resistance to the flow of water through 5 metres of 3/16" tubing and you may find that friction alone will be insufficient to hold in place plastic tubing leading from the water supply in the house. There is nothing worse than having the water line blow off in your absence and finding your workshop flooded when you return. So play it safe. One neat solution to this problem is to use the metal fitting and 1/4" o.d. high-density polyethylene tubing used for connecting a humidifier to the house water supply line. It uses compression fittings and can withstand high pressure. These little kits are inexpensive (\$12-ish) and come with 25 ft of high-pressure polyethylene tubing, a length which is convenient when the water supply is not adjacent to the still. Alternatively you could use copper tubing all the way from the house supply to the still. The drain from the cooling coil involves no pressure so any type of tubing will do.

Column support

A fractionating still is rather tall and needs some support, particularly one made from glass. Some people build their still close to a wall so that they can use brackets to support the column and the collection bottle. This arrangement is shown in Figure 11. Another method, which is much better although more expensive, is to make or purchase a kitchen cabinet 36" high, put the boiler in the cupboard and bring the column up through a hole in the counter-top. (see Figure 12). This hole either should be large enough to accommodate both the column and the insulating sleeve around it, or just the size of the glass column with separate insulating sleeves above and below the counter-top. And while on the subject of insulating sleeves, remember that the column should be well insulated during the second stage of fractional distillation (but not the 1st stage) in order to have a steady temperature gradient from top to bottom. A split foam sleeve is useful because then you can open the slit from time-to-time and peek inside. Use a spirit level to ensure that the column is upright. Not only does the tabletop support the column very firmly but it can also support the stand on which you place the collection bottle. Additionally, a table is useful for holding a digital thermometer and for writing up your notes.

CAUTION!! Be extremely careful when assembling the two metal and the two glass components of the still because any non-alignment of the glass and metal, or bending and distortion, may lead to breakage. We strongly recommend, therefore, that the location of the boiler be fixed, as well as any clamps which will be holding the column vertical. Then carefully install the still components and leave well alone. The cooling coil in the glass tube at the top should have flexible water lines so as to avoid any lateral drag which might crack the glass.

There are many refinements you can make to this set-up. For example, a set of built-in drawers is very useful and such an arrangement is shown in Figure 12. Then, if you put the whole thing on castors, with the boiler resting on the floor of the cupboard, you can wheel the still from one part of the room to another or even into a closet or another room.

Collection of alcohol.

The draw-off valve where the alcohol emerges from the still will be about 600 mm above the counter-top so there is plenty of room for any size collection bottle. We use a length of $\frac{1}{4}$ " or $\frac{3}{8}$ " copper tubing from the draw-off valve to the receiving bottle so that the emerging alcohol, which is hot, is air-cooled as it runs down the room-temperature copper tubing.

So there's The Carriage Still in all its glory. In the next chapter we'll take a look at how to use it.

Figure 11. The Carriage Still – Wall mounted



Figure 12. **The Carriage Still - Cabinet mounted**



PROCEDURES

The use of the carriage still will be illustrated by making vodka. Vodka was chosen for several reasons:

1. It is the least complicated of all alcoholic beverages, with no subjective judgements involved. As defined by the Bureau of Alcohol, Tobacco & Firearms (BATF) in the United States, vodka is “a neutral spirit so distilled as to be without distinctive character, aroma, taste or color”. This means that the procedure involves nothing more nor less than the complete removal of all extraneous substances and all congeners to leave pure, unadulterated ethyl alcohol. This is very much simpler than the selective removal of some congeners but not others in order to leave a few which have a taste.
2. Ethyl alcohol is the common denominator in all alcoholic beverages. Speaking simplistically, everything else, from beer to wine to whiskey is nothing but flavoured alcohol. As we shall read later, the hundreds (dozens?) of different vodkas available nowadays all start life as pure 40% ethyl alcohol and then have their unique flavouring added.
3. If you have equipment which is capable of removing all the impurities, the congeners, it means you have equipment which can be throttled back in order to leave some of them. In a later chapter we'll deal with this “throttling back” of the carriage still whereby some of the flavoursome substances are left behind.

Production of alcohol.

Before alcohol can be purified in a still you have to make it. This is pretty obvious, particularly to you brewers and vintners who have been making beer and wine for years. The point we wish to make here is that you are not making beer or wine --- you are making alcohol. Since any flavour will be removed by distillation, you don't need to worry about whether this was a good year or a bad year for grapes, or the strain of yeast you use, or the temperature, or whether the sugar came from sugarcane, potatoes, corn, or milk (lactose). What we're looking for is the cheapest, fastest and least troublesome way to make alcohol. No need for airlocks, or nutrients, or special yeasts which ferment rapidly (unless you are keen to get the job over with or have a big party coming up). So this is a different operation to the one you are used to and you may be depressed by how crude it is. Cheer up! The fun comes later when you start distilling.

The fermenter. No doubt the beer- and wine-makers among you will wish to use the carboys (or whatever) you have used successfully up to now for the fermentation, and there's nothing wrong with that, but if you're starting from scratch we suggest that a cheap and effective alternative is to use a laundry-tub. It stands on 4 legs so is a convenient height, holds about 50/60 litres of sugar solution, and has a convenient tailpipe underneath for transferring the beer to the still. Attach a ¾” ball valve and hose bib to the tailpipe of the drain. Airlocks not being so vital one can simply cover the tub with a sheet of glass. For a fast, efficient fermentation a heater to maintain the temperature in the optimum 33° to 35° C. range is required, and an aquarium heater does a good job. A submersible aquarium pump works beautifully for circulating the liquid and is particularly helpful at the start when dissolving the sugar.

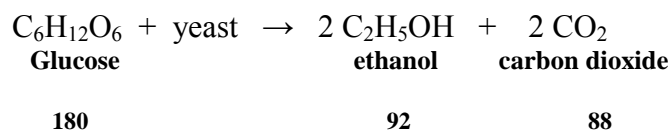
Procedure. We recommend using 10 kg sugar (ordinary supermarket table sugar) as carbohydrate source. It's cheap, pure and readily available. Close the ball valve on the drain line and put a rubber stopper in the drain hole. Dump the sugar into the laundry tub, add 50 litres of cold water, put in a hydrometer, start the circulating pump, switch on the heater and slowly sprinkle 150 grams of baker's yeast (the dry, active, powdered variety which costs about Cdn \$4.25 per 500 g.) onto the top of the water. Keep the heat on until the temperature has risen to 33° to 35° C., the optimum temperature range for a fast fermentation, and maintain it at that level for 5/6 days. The SG will drop from about 1.06 to about 0.99 and you'll have 50 litres of a crude 8% "beer". The reason for starting with cold water and adding the yeast before the sugar has dissolved is to prevent too vigorous a reaction at the start and foaming. No nutrients and no special yeasts are needed. Vacuum-packed baker's yeast is very satisfactory, but make very sure that it is fresh with a "use-by" date many months or even a year ahead. Refrigerate the unused portion.

After the S.G. has dropped to 0.99 stop the circulating pump, switch off the heater, remove the hydrometer, and let stand for a few hours (or even overnight) to allow some of the yeast to settle out on the bottom of the fermenter. Remove the rubber drain-stopper and connect a short length of rubber hose between the fermenter and the boiler. A washing machine hose with two female ends is ideal for this.

Concentration vs amount.

There is a very great deal of confusion in the minds of government officials about the difference between concentration and amount --- this is why they put a higher tax on spirits than on beer, even for the same amount of alcohol. The same confusion exists, unfortunately, in the minds of the general public.

The theoretical maximum yield of alcohol from sugar is based on the following equation:



180 grams of glucose will lead to 92 grams of ethanol using ordinary baker's yeast (provided it's fresh and used properly) and there's nothing you can do and no yeast you can use which will make the slightest difference to this yield. That's because the alcohol comes from the sugar, not from the yeast. Special yeasts may speed up the fermentation, reducing the time from, say, 5 days to 3, which could be important to many people, but they shouldn't expect to get more alcohol.

Beer stripping. Stage 1.

The distillation of beer to produce pure alcohol is a 2-stage process, both commercially and at home, or even three if you want your alcohol “purer-than-pure” or if you think you may have done a less than perfect job during the first two stages. The first stage is called “beer-stripping” and consists of nothing more than a quick and dirty stripping of the beer to remove most of the alcohol and leave behind most of the water, some of the impurities and all of the spent yeast. We shall refer to the product of beer stripping as “high wine”. Some people prefer to use the term “low wine” but we prefer “high wine”. It will be 40 or 50% alcohol depending on how much reflux you have used. The second stage of purification is called “rectification”.

The volume of the boiler can be either 25 or 50 litres. Let’s take 25 litres in order to have something definite to work with. We have 50 litres of beer. The boiler shouldn’t be more than about 2/3 full when stripping because of foaming, so this means three separate strippings of about 17 litres of beer each time, the high wine collected from each batch being combined for the second stage of purification. If you had used a 50 litre boiler you could have managed with two beer strippings rather than three.

Operating the still. Put about 17 litres of beer in the boiler, start water running through the cooling coil, close the draw-off needle valve, insulate the column, switch on the full 750 watts and wait. After a couple of hours vapour will be detected by sight and feel rising up in the column. When it reaches the thermometer the temperature will shoot up to somewhere in the 70’s deg. C. The vapour will continue to rise, reach the cooling coil, and liquid will then start to pour off the bottom of the coil and back down through the still-head and through the packing into the boiler. Let it run for a few minutes. All the liquid coming up from the boiler is being returned to the boiler and this situation is termed “total reflux”. You may notice that the temperature may drop during this period to the mid 70’s. This is because the very volatile acetone and methanol are rising to the top of the column and they have very low boiling points. Draw off a spoonful of liquid through the draw-off valve and smell it. It smells terrible. Discard it, or save it in a bottle to clean spots off the rug! Repeat this a few times to get rid of most of the worst impurities and then settle down to the beer-stripping proper.

When you use the still for the first time you should measure the boil-up rate. With 750 watts input and the draw-off valve wide open this is likely to be around 50 ml per minute, but measure it with a measuring cylinder and stopwatch. You only need to do it the once. For the sake of argument let’s say that the boil-up rate is, in fact, 50 ml/minute. (Note. If you were using a 1500 watt heater the boil-up rate would be closer to 90 ml/min.).

During beer stripping the draw-off valve could be set anywhere between fully open and fully closed. In the first case you’d have something approaching a pot still while in the second case there would be nothing to collect. Where to set the valve?

We suggest you set the draw-off valve almost completely open. With the insulation removed from the column there will be enough air-cooling to provide the small amount of reflux you need and this reflux will be flowing back down the column to help with the purification process.

The temperature will slowly rise over the course of the next few hours, and when it reaches about 98° C. you should switch off because you'll have stripped off the bulk of the ethanol and it's not worth the extra time and electricity to continue further. Switch off, allow the boiler to cool somewhat, and then send the stillage from the boiler to drain. Flush out the boiler by running a little cold water down through the column, thereby flushing out the packing also. No need to be too conscientious about this because you're now going to repeat the operation with the second and third 17 litre batches of beer. Combine the three batches of high wine for the second stage purification.

Rectification. Stage 2.

The efficiency of a fractionating column in separating liquids of different boiling points is dependent upon two factors. One is the length of column and the type of column packing, i.e. its physical characteristics. The second is the reflux ratio, i.e. the way in which the column is used.

As we have mentioned several times, the principle of fractional distillation requires that the vapours rising up the column encounter the condensed liquid running back down the column. It has been found by experience that a reflux ratio of about 10:1 gives very good results. Thus, if the total reflux rate were 50 ml/minute (determined by measuring the output with the draw-off valve wide open) then 10% of this or 5 ml/min. could be drawn off for use. The other 90% would be allowed to flow back down the column to provide the multiple mini-redistillations on the surfaces within the packing. It will be appreciated that the 10:1 ratio is not critical ... 8:1 would be acceptable and 12:1 even more so. The 10:1 figure is simply a reasonable value which is known to give good results with this type of packing. When we refluxed just 20% of the total reflux during beer stripping, and drew off 80%, the reflux ratio was 10:8 and far too small a ratio to separate out all the impurities, but it will have separated out many of them and we can now go to work on the much smaller volume of somewhat purer alcohol.

Procedure. Combine the three batches of high wine from the 1st stage beer-stripping and add them to the boiler. Add a few litres of water if necessary to ensure that the heating element remains covered with liquid even when the distillation is complete. Heating elements are usually installed near the bottom of hot water heaters, but not right at the bottom, so when you first buy your boiler, remove the element and pour in water until it flows out of the hole. This volume, plus a couple of litres extra to cover the element, is the minimum volume you must have in the boiler when in use. You will be collecting 4 to 5 litres of distillate in this 2nd stage so, knowing how much high wine you have added, a simple calculation will tell you if extra water is needed.

Insulate the column for this 2nd stage. Then, in exactly the same manner as with the 1st stage, switch on the 750 watt heating element, start cold water flowing through the condenser, and close the draw-off valve.

The next several hours are spent equilibrating the column. This is the period during which the various components of the mixture sort themselves out with the more volatile components moving to the top of the column and the least volatile moving to the bottom. To understand why this takes time consider the following homely analogy. A long corridor is packed with people of different heights waiting to get through a door at the end in order to enter the store. The store manager announces that before he lets anyone in he wants everyone to sort themselves out by height, the short people at the front and the tall people at the rear, with a uniform height gradient between. There is a lot of shuffling about and it takes quite a while for a perfectly even gradient from shortest to tallest to be established. The same is true of a mixture of liquids of different B.P. in a packed column.

The progress of equilibration can be followed by watching the temperature of the vapour at the top of the column. Ethyl alcohol has a boiling point between 78 and 79 deg. C., the exact figure depending greatly on the atmospheric pressure (see Appendix I), while the heads such as acetone and methanol have a lower B.P. The thermometer will register this and, although a temperature of 78° C. might be registered at first it may slowly fall a little as the acetone and methanol find their way to the head of the queue. Periodically crack open the valve in the still-head to bleed off these heads into a spoon, leaving room for the ethanol to rise a bit higher in the column. Referring back to the analogy of people of different height shuffling about, if you let some of the shorter people through the door, even if the sorting out isn't quite complete and a few taller people slip through as well, you will make it easier for the remainder to get organized. A suitable withdrawal rate would be 2 or 3 drops per second.

These heads not only have a strong smell (test them with a spoon) but also a terrible taste so you can congratulate yourself that you're getting rid of them and not drinking them. They are highly inflammable and make an excellent fondue fuel or starter fluid for the barbecue. As the heads are bled off the temperature will slowly stabilize at 78+ deg. C. indicating that most of the heads have now been drawn off and ethyl alcohol is beginning to appear.

The alcohol-water azeotrope.

Water is an important constituent of the fermentation broth and with a boiling point of 100 deg. C. lies intermediate between the least and the most volatile components of the mixture. It has one important difference from the other components, however, in that it forms an azeotrope with ethanol. An azeotrope is a mixture of two liquids with a boiling point lower than either constituent. In the case of ethanol and water the azeotrope occurs at a mixture of about 96** percent ethanol (v/v) and 4 percent water. The boiling point of this azeotrope is 78.1° C. whereas the B.P. of 100% ethanol is 78.4 °C. As far as the system is concerned it "thinks" that this mixture of ethanol and water is a single liquid with the lower boiling point of 78.1° C. and proceeds to separate it on that basis. The ethanol which is purified by a fractionating column is not, therefore, pure 100 percent ethanol but pure 96 percent, the "impurity" being pure water. No amount of re-distillation under the conditions we are using will influence this percentage.

If it is absolutely essential to remove all the water, for example if it is to be mixed with gasoline to produce gasohol, then benzene can be added to break the azeotrope, followed by re-

distillation. For our purposes, however, where we are going to dilute the alcohol with water to 40 percent anyway, the presence of 4 percent water is of no consequence.

**Footnote. In the literature you will find slightly different values for the azeotrope composition, all hovering around 96%. One reason for this is that the percentage can be expressed either volumetrically (v/v) or by weight (w/w). Plus v/w and w/v! There is a difference because ethyl alcohol has a specific gravity of 0.8 compared to 1.0 for water. For example, 96% ethanol v/v works out to 95% w/w. If so inclined you may worry about this, but a more important question is --- should a good martini be shaken or stirred!

Temperature measurement

A word must be said here about the accuracy of thermometers. A thermometer purchased from a scientific supply house should be accurate to 0.1 deg. C. but don't count on it. Thermometers purchased at a drugstore or a winemaker's supply store can be off by as much as 2 degrees. We recommend that you always check the accuracy of a thermometer by placing it in boiling water and recording the temperature. You may be lucky and find you have purchased one which reads 100 deg. C. but if it doesn't, simply make a note of the deviation and apply the appropriate correction whenever you use it to read a temperature. And don't forget that atmospheric pressure affects the boiling point of liquids quite significantly. Digital thermometers are extremely useful in that they are much easier to read than the glass type, sit right in front of you on the bench and are accurate enough for our purposes, more accurate in many cases than the other sort.

Fortunately for us it is not necessary to rely on the exact temperature during a fractional distillation in order to indicate when the heads have finished coming over and it is safe to start collecting ethanol. For one thing the temperature is influenced markedly by atmospheric pressure (see Appendix I). Constancy of temperature is the most important indicator. Thus, if the temperature has risen to just over 78 deg. C. and has stayed there for 15 minutes or so you can be fairly sure that all the heads are gone. It is also pointless to quote the azeotrope temperature to two places of decimals, e.g. 78.15 when a) it varies so markedly with pressure, and b) no other boiling point, including ethanol itself, goes beyond one decimal point.

Briefly then, proceed as follows: Operate under total reflux for a couple of hours to equilibrate the column, bleeding off the heads periodically into a spoon and sniffing them until there is very little smell and until the temperature remains constant at just over 78° C. Then start to collect the distillate at a 10:1 reflux ratio by gently opening the valve in the still-head.

It is not very convenient to set the collection valve each time you carry out a distillation by using the volume which flows out in one minute. It is too cumbersome. A better method is to laboriously find a valve-setting which does deliver 5 ml per minute and then count drops using a stopwatch. Thus, 5 ml per minute might represent, say, 75 drops in 30 seconds. Knowing this you can quickly adjust the collection valve to the right setting by counting drops with a stopwatch. A note of interest is that the size of a drop depends upon the radius of curvature of the surface from which it is dropping, so a ¼" diameter collection tube will give you nice fat drops and a smaller number to count.

Collect at least 250 ml of this first distillate and put to one side for future processing and then start to collect the purest alcohol in a clean receiver. Throughout this early phase test the distillate with your nose to see if you can detect any trace of heads.

The 250 ml or so of early distillate which have been put aside may be perfectly pure but the nose and the palate are extremely sensitive organs, particularly the palate, (and particularly your wife's palate!), and she would quickly detect an off-flavour if it got through into her final drink. Even commercial producers, with a laboratory full of sophisticated analytical equipment such as gas chromatographs, rely on taste and odour panels to judge the quality of their product. It has the grand name of "organoleptic" testing and is the ultimate in testing for palatability. Play it safe, therefore, and put aside a generous portion of the initial distillate, even as much as 500 ml. It will not be wasted because, in a few weeks time, when a number of distillations have been completed and several litres of doubtful distillate accumulated, an equal volume of water can be added before redistilling and really pure alcohol recovered from it. It will amount to a triple distillation and be exceptionally pure.

When all the ethyl alcohol has distilled over, which may take as long as 14 hours, the temperature will start to rise as the higher boiling point "tails" appear. Experience will tell you when to expect this to happen and you should be present and start switching receivers well ahead of this point so that only a small volume of alcohol will be contaminated. The last receiver containing a trace of tails can be added to the discard bottle for later purification.

When the fractional distillation is complete the packing in the column will be flooded with tails. These should be thoroughly washed from the column by pouring generous quantities of water down from the top.

When carrying out a fractional distillation for the first time the rate of production of pure alcohol will seem to be rather slow. At a few drops per second one can believe that it will take forever to produce a reasonable amount and there will be a tendency to open the collection valve a little wider to increase the flow. Resist this temptation and be patient. The apparatus requires no attention and it is surprising how much alcohol is produced at a flow rate of 2 or 3 drops per second for several hours. Thus, at 750 watts input to the boiler and a draw-off rate of about 250 ml. per hour, about 4 litres of pure, 96% alcohol will be obtained in an 16 hour day (overnight). This, when diluted to 40% with water, will provide over 9½ litres of vodka.

Yield of alcohol

The theoretical yield of pure, 100 percent alcohol from 10 kg of cane sugar is 6.25 litres. This is equivalent to 6.58 litres of 96 percent alcohol or 15.63 litres of 40 percent alcohol. While it is possible to approach such a yield, you will find in practice that you only reach 70-80% of this value due to various losses along the way. One place where you can expect losses to occur is in the fermentation process ----for example, you may not have left the brew long enough for all the sugar to have been completely used up. Or the yeast may have lost some of its activity. And then there are all those unwanted side reactions which produce the congeners such as methanol, fusel oils, etc., instead of ethanol. It is understood that turbo yeast can solve many of these

problems and is worth serious consideration. However, the major place where losses occur is in the last stages of beer-stripping where time and energy consumption require that the stripping cease before the last drop of alcohol has been extracted. As a result, the practical yield of 96 percent alcohol is likely to be no better than about 5 litres which is a yield of 73% of the theoretical value. This is equivalent to 11½ litres of vodka or gin, which is not too bad coming from \$11-worth of sugar and \$1.50-worth of yeast.

In commercial practice such a low yield would not be tolerated, but for us it should be quite acceptable, particularly on economic grounds. Higher yields, which are certainly possible, offer an interesting challenge to the dedicated amateur.

Water quality

A word must be said about the quality of water used to dilute pure 96 percent alcohol to the 40 percent which is characteristic of most spirits. Unless the water is very soft, hardness will precipitate out when alcohol is added because the calcium and magnesium salts which constitute the hardness are less soluble in an alcohol-water mixture than they are in water alone. Depending upon the degree of hardness the effect will vary from a cloudiness to a white precipitate which falls to the bottom of the bottle.

The effect described above is perfectly harmless, the white precipitate being nothing more than the hardness present in the original water before the alcohol had been added. It is actually quite good for you. However, it is aesthetically unpleasing and should be avoided by using distilled or demineralized water obtainable very cheaply from supermarkets and from certain stores which make distilled water on the premises. If you have a water-softener in your house, or if your water is naturally soft, you'll have no problem.

Storage: Store your pure 96% alcohol in glass, not in plastic. A few 1½ litre wine bottles with screw caps are ideal. There is, of course, no need to "mature" vodka; it is ready for drinking the day you make it.

Alcoholic beverages

Up to now we have been dealing with the technology of distillation, and explaining just how to remove all the congeners, all the taste, all the character to leave a pure “unadulterated” ethyl alcohol. And this has been said proudly, as though taste or flavour was something to be ashamed of and shunned at all costs. So now it’s time to back off a little and talk about taste.

Vodka.

As mentioned previously, the BATF definition of vodka is “a neutral spirit so distilled as to be without distinctive character, aroma, taste or color”. Aleksander Orekhov, the Russian-born owner of Red, a Soho bar that offers some 40 different vodkas, makes no apology for saying that the best vodka is one that has no real flavour at all. When you have swallowed it, he says, “there should be no aftertaste”. We have made pure ethyl alcohol, diluted it to vodka strength (40%) and tasted it and, sure enough, it has no taste, just an astringent feeling on the tongue. Naturally, however, having no taste doesn’t mean that it’s completely innocuous --- it has the normal physiological effect on the human body, producing the “buzz” which is so characteristic of all alcoholic drinks.

There are many who will contest the above definition of vodka and the statement that a true vodka has no taste. Aficionados will point to the well-known differences between vodkas from Russia, Poland, Ukraine, Finland, N. America, or the differences between vodkas made from grain, potatoes, wine or milk (lactose). They have a point. European vodkas do have a taste, whereas N. American vodkas have very little, but the explanation may be as follows:

A hundred years ago flavourless vodka was something of a novelty. The distillers of the day did not have the technical means or know-how to remove all the congeners, so the spirit tasted rough and fiery. To combat this they macerated fruit or herbs in the vodka or, in the Zubrovka brand, bison grass. Nowadays, with much better equipment available, it is easy to make pure and tasteless vodka, as we ourselves do, and add the flavouring afterwards. The modern method also extends the range of flavours greatly because there is no rank flavour to cover up and you can add whatever you like. So, although “true” vodka may have no flavour by BATF definition, in practice most of them do, but then they should properly be referred to as “flavoured vodkas”.

Flavoured vodka.

When a distiller flavours his vodka he does it very lightly using certain grasses or herbs, so delicately that it can barely be detected, in which case the source of the flavouring is not mentioned. Or glycerine is added to give the vodka smoothness and body. The use of such additives is allowed to remain a subtle mystery in order to tempt the palates of vodka aficionados around the world.

Recently, however, much more strongly flavoured vodkas have been introduced into the market, and not just by newcomers but by venerable and highly respected Russian distillers such as Stolichnaya. They are now all the rage and flavours include everything you can think of ----

raspberry, strawberry, peach, vanilla, coffee, cinnamon and so on. For a first class pepper vodka place a number of small, dried, hot red peppers into the pure vodka you've made with the carriage still and wait for several weeks. Decant and enjoy. And remember, what you can do with red peppers you can do with dill, or coriander, or cardamom, or raspberries, etc., etc., etc. No-one pretends that these flavoured vodkas come from some special potato grown in a secret field in a remote part of Poland --- they are boldly proclaimed as "lemon vodka", "pepper vodka", etc.

Another, more traditional way to make a delicately flavoured vodka is to carry out a slightly "imperfect" fractional distillation so that trace amounts of the natural flavours in the original source of carbohydrate --- potatoes or grain --- are retained. This procedure will be discussed a bit later but is quite tricky because you're involved with subjective judgements as to which congeners to retain and which to discard.

Essences.

It may seem like a cop-out but you can buy essences with just about every flavour known to man. Many companies make and sell these essences but one of the best is the Swedish company Partyman AB (7), the presiding genius of which is Gert Strand. He has at least 200 essences for you to play around with, everything from lemon vodka to dark rum to various schnapps, to whiskies. Many of them are excellent and you'd be hard-pressed to do better yourself. All you have to provide is the alcohol, and of course it should be a pure and tasteless alcohol so it won't impart any flavour of its own. Just the kick.

As an example of an essence you can make yourself, using natural ingredients and steam distillation, we include in Appendix IV the recipe for making a gin essence. By adding a few ml of this essence to vodka you will convert it to London Dry Gin. This could serve as a model for the production of other essences based on other botanicals. One of the big advantages of using essences with vodka is that the product never contains a trace of harmful congeners such as methanol and fusel oils. It will be pure alcohol plus pure flavouring.

Liqueurs.

There are many books available on making your own liqueurs, and usually the recipes involve two different procedures. One involves steeping the fruit in vodka to extract the flavor and then adding sugar. The other involves the use of a purchased essence, again with vodka as the alcoholic base. In both cases vodka is involved, and if you know how to make it yourself for \$1+ per litre (which you do) you're home to the races.

Chacun son goût

Is there such a thing as a "bad" taste or a "good" taste? Or should we talk about tastes we like and tastes we don't like? Not everyone likes the taste of curry whereas others dote on it. Are there any absolutes? Or are we being influenced by what people say, by the price, by the label, by the opinion of "experts", by the history and provenance? No-one set out to make a scotch whisky or a rum or a schnapps; they set out to make a strong drink using the primitive equipment they had at the time and gradually refined it over the years as a result of their own experience and criticism from others. We now drink what we've been "taught" to drink. Some scotch

whiskies are advertised as being made with water which has trickled over rocks a million years old, and the unpronounceable names given to single malts makes us certain that these must be very rare whiskies indeed. We sip them slowly and appreciatively. Some vodkas are advertised as pure alcohol diluted to 40% with melted ice from glaciers in the high arctic tens of thousands of years old.

We are not trying to be argumentative or cynical in making these comments. They are very relevant to anyone trying to emulate a commercial alcoholic beverage. Our advice to you is to do what everyone else has done over the centuries and play around with your equipment and raw materials, experiment until you produce something which pleases you. Your equipment and knowledge is far superior to anything your ancestors had available, and they managed to produce something palatable. Of course in those days they didn't have a lot of choice so were forced to make the best of it, and now, in the year 2001, their potions have become hallowed by tradition. Not knowing how to make vodka they made a rot-gut whiskey, worked on it, and eventually learned to love it.

Enough of these philosophical musings. Let's get down to cases. The carriage still was specifically designed to remove all traces of extraneous substances --- that is to say congeners or flavours (both good and bad) --- from the original beer, so obviously we have to back off a bit so that some of these flavours get through. That shouldn't be too difficult --- if we know how to eliminate congeners completely we ought to know how to retain a few of them.

The still.

To start with, Figure 13 shows a commercial rum still taken from "The Alcohol Textbook" by Dr. John Murtagh (6).

There are many different types of rum still. Also brandy and whiskey stills, but this diagram illustrates a point we wish to make, i.e. that to retain flavour a pot still may be used but some reflux provided in order to reduce the amount and type of congeners distilling over. Note the small number of bubble-cap trays and the somewhat primitive reflux condenser system at the top which is nothing more than a tank of water. The vapours which manage to get past the reflux system are condensed in a coil immersed in a cold water tank.

Turning now to the carriage still, it is clear from everything written up to now that we have to modify the operation in some way if we want some of the congeners to get through. There are two ways to do this. One would be to remove some of the packing from the column, thereby reducing the number of liquid/vapour interchanges which take place during reflux in the column. It would be equivalent to the commercial rum still shown in Fig. 13.

The second method would be to leave the packing intact but change the reflux ratio. You will remember that during high-purity reflux distillation for vodka we used a reflux ratio of 10:1, that is to say we returned 9 parts of the condensed vapour to the column while drawing off 1 part for use. If we changed the reflux ratio to, say, 10:8, we'd be drawing off 8 parts of condensate

for every 2 parts we allowed to cascade back down the column. Obviously the separation of congeners in the column would be greatly impaired and the product would contain some of them --- and taste of them. Ian Smiley gives a very good outline of this procedure in his description of the production of corn whiskey (5) and states that “This means that a high-separation fractionating still offers very precise control over separation level by simply adjusting the proportion of reflux, thereby making it possible to produce spirits... such as whiskey in a fractionating still. And it is because of this precise control over separation level that the author (Smiley) has chosen a fractionating still in this text as the design for making whiskey” (5). He used an earlier model fractionating still than the carriage still described in this text, but the differences are merely cosmetic. The carriage still would work just as well. For the full description of Smiley’s procedure you should read his book.

None of the above tells you precisely what reflux ratio to use. Nor does it tell you how much of the first material (the heads) distilling over you should discard. You’ll have to indulge in that well-known scientific procedure called “trial-and-error” or “suck-it-and-see”. Collect the distillate in a dozen or more separate receiving bottles and sample each one by taste and smell. Probably the first bottles of distillate will contain acetone and methanol and should be discarded, and the same holds true for the tails --- you won’t want to go on distilling and collecting the product when the really noxious, high B.P. material e.g. fusel oils, are coming over. But take your time assessing the various middle fractions and solicit the help of your friends in arriving at a consensus of what is palatable and what is not.

Figure 13. Pot still with bubble-cap tray section

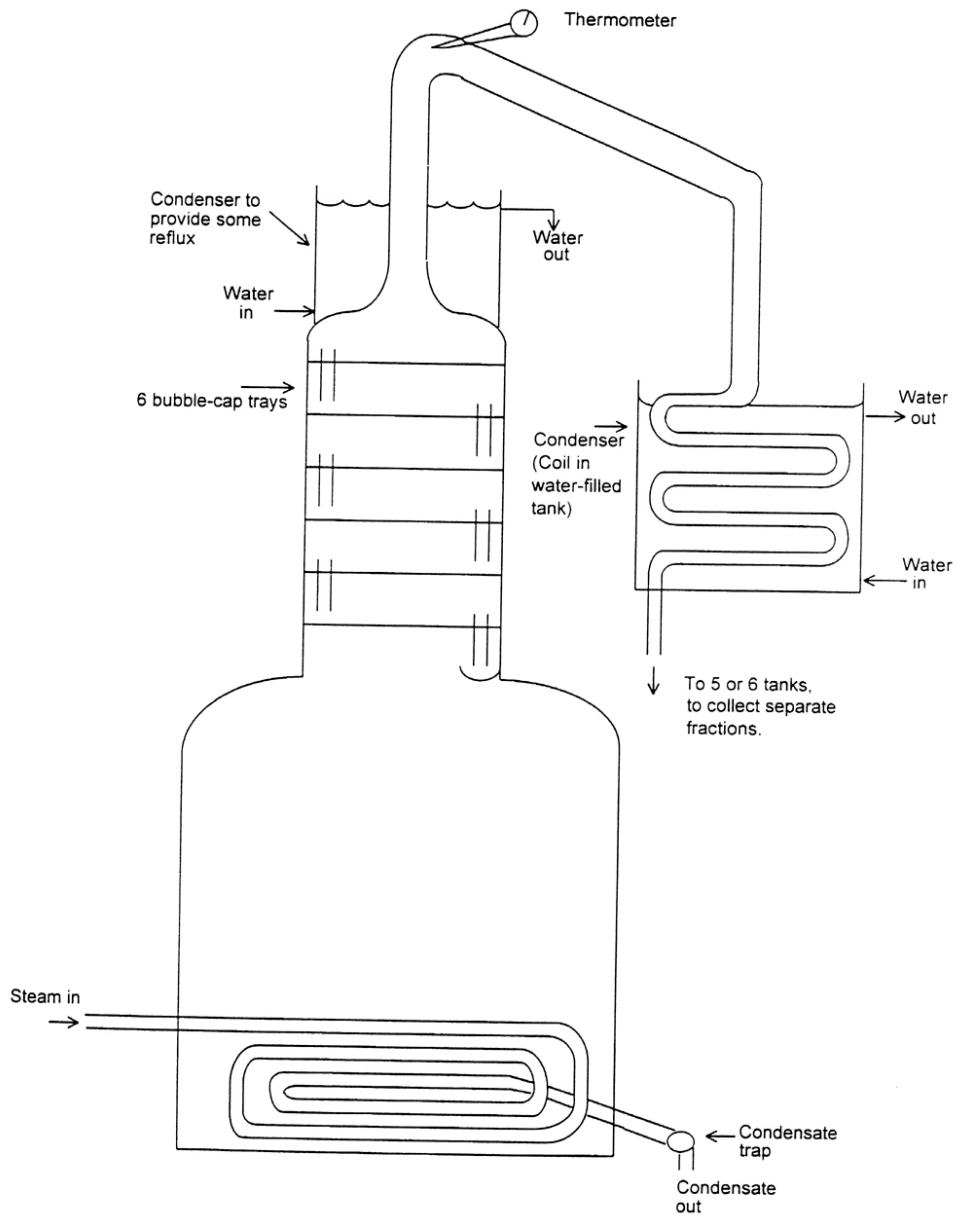


Figure 15.3 Pot still with bubble-cap tray section

The flavour.

Where does the flavor come from? We've been talking about the retention of flavor but what is the source of this flavor? The source is the fruit, berries, vegetable or other plant material which you fermented. In the book by Ian Smiley referred to above "Making Pure Corn Whiskey" you will not be surprised to learn that he started with corn. Brandy is made from wine, which of course is derived from grapes. Then there's tequila which comes from the agave cactus, and a whole range of schnapps are made where the starting point is plums, or pears, cherries (kirsch) or, indeed, any fruit you can think of. What a wealth of experimentation there is ahead of you! An old lady we knew in Switzerland had a lot of cherry trees and each year used to fill a large wooden barrel with them, put on the lid and leave them for a month. Occasionally we'd help her roll the barrel around and then heave it upright again. The cherries would ferment, using the wild yeasts present on their skins. Fermentation being an anaerobic reaction she made sure no air entered the barrel. At the end of the month she would filter the mash and distil it in a quite primitive pot still, a still having lots of surface on the upstream side of the contraption to get a little condensation of vapour and reflux. The clear liquid which dripped from her still was kirsch and delicious.

Comment.

The above discussion is very brief. Nowhere do we give the detailed information required to make a schnapps, an eau-de-vie, a liqueur, a rum, brandy or whiskey. The reason is that the preparation of a palatable beverage by distilling is very much a matter of trial-and-error. Use Smiley's book (5) as a guide and move on from there. This is what it's all about. This is how it becomes a fascinating hobby and one of which you will never tire. M. Arnaud de Villeneuve had it about right in 1250 when he referred to distilled wine as "eau-de-vie" or *Water of Life*.

Steeping

Perhaps the simplest method of flavouring alcohol is to make some vodka (40% alcohol) and steep something in it. Thus, you will find in most books on making your own liqueurs a number of recipes in which fruit such as raspberries, oranges, cherries, etc. is steeped in vodka for several months. At the end of this time a lot of the flavour in the fruit and some of the colour has passed out into the alcohol. Then a large quantity of sugar is added to give the sweetness and syrupy consistency characteristic of liqueurs. If you don't add the sugar you'll have a flavoured vodka, and the longer the steeping time the stronger the flavor. And the shorter the steeping time the more delicate the flavour.

AMATEUR DISTILLATION AND THE LAW

There is not much point in building a beautiful still if you're not allowed to use it, and the law in N. America is quite definite about this. Read about it, they say, but don't do it. However, in Canada at least, the penalties don't seem to be too severe. In a recent case (January 2001) a man who was caught not only making stills but selling them via the Internet was fined just \$575 or 10 days in jail. He chose jail on the grounds that, if Gandhi and Nelson Mandela were prepared to go to jail for their principles, then so was he.

In Appendix V, taken verbatim from the previous book in this series (3), the whole subject of legality is dealt with at some length, particularly analyzing why governments are so opposed to a simple purification procedure, using a perfectly legal substrate (beer) as the starting point. The case of New Zealand, which legalized amateur distillation in 1996, is cited frequently since it is obviously a model which N. America and Europe should study carefully. And emulate.

One of the most important reasons for prohibiting amateur distilling may be the perceived harm which such a move might cause commercial distilleries ---- with the attendant drop in sales and loss of government tax revenue. A potential loss of tax revenue brings governments officials out in hives.

If this is one of the reasons why the law remains in force today we would like to draw attention to the figures in the following table, derived from the Annual Statistical Report of the Association of Canadian Distillers. It gives the statistics for sales of alcoholic beverages in Canada from 1981 to 2000, breaking them down into beer, wine and spirits, and putting all the figures on the same basis of "litres of absolute alcohol", thereby making allowances for alcohol concentration.

Litres of Absolute (100%) Alcohol (LAA)

Year	Beer (000's LAA)	Wine (000's LAA)	Spirits (000's LAA)
1981	100,353	25,205	77,949
1985	103,672	29,516	67,447
1990	105,676	28,254	57,344
1995	100,752	26,700	45,286
2000	101,735	28,565	48,093

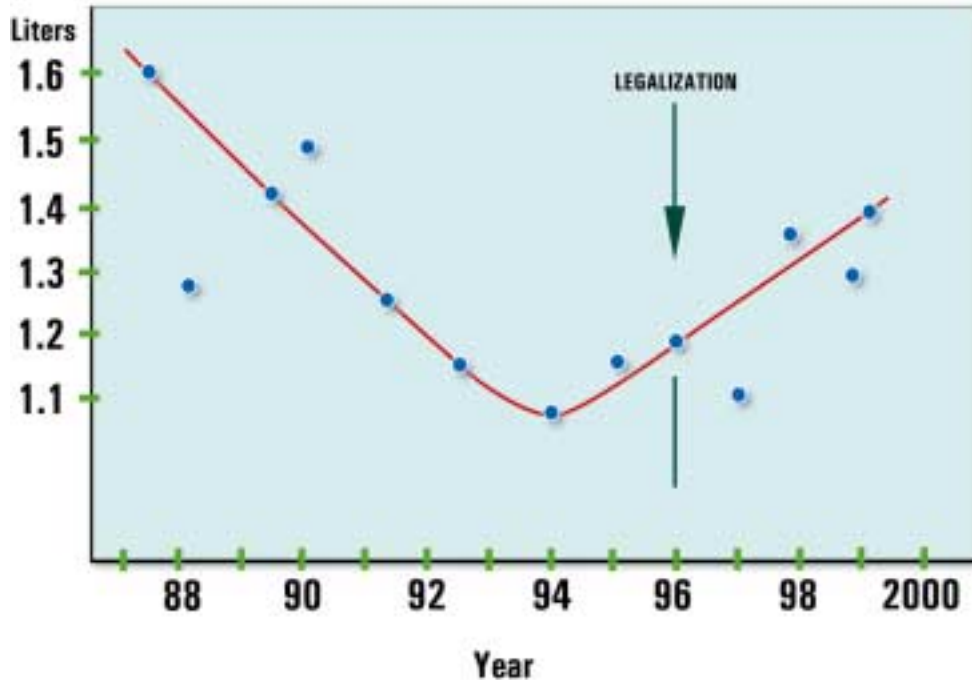
What this table shows is that while beer and wine sales have stayed fairly level, spirits sales have dropped dramatically. On a per capita basis spirits sales over the same period dropped from 4.46 to 2.06 LAA, much less than half. Such figures naturally give rise to great concern among distillers, and the thought of amateur production making further inroads into their sales produces what may be termed “a negative reaction”. This negative reaction is then passed on to governments, and we should remind ourselves that the distilling companies have lobby groups in Ottawa and Washington to make their case. It would be unfair to suggest that they may be tempted to contribute to party funds.

So we invite commercial distillers in Canada to consider this point. Beer and wine sales have not been affected during a period when amateurs have been making lots of beer and wine. Gallons of it. Litres of it. During the same period spirit sales have dropped while amateurs have not been allowed to distil a single drop. How do we explain this? Could the explanation be that the home production of an alcoholic beverage increases interest in that beverage? Increases, not decreases. There are all kinds of magazines available on beer- and wine-making, stores where you can buy the ingredients, bottles, corks, labels, etc. for the home brewer and home vintner, discussion groups on the Internet where enthusiasts discuss their likes and dislikes, home-brew shops, brew clubs, wine-tasting gatherings, and so on. It’s a fun hobby and particularly appeals to the young and the young at heart. By contrast, spirits remain a cold, distant, commercial product, completely divorced from the interests and activities of fun-loving youth. They aren’t involved. They’re not part of the action.

This situation is changing rapidly in New Zealand where amateur distilling has been legal since 1996. It is now a hobby, with all the interest, discussions and get-togethers which any hobby generates. There is considerable activity on the Internet as people discuss the merits of one type of equipment compared to another, an improved procedure someone has discovered, the differences between different types of yeast, the substrates required for various whiskies, rums, brandies, schnapps, etc. The figures for spirits consumption in New Zealand are quite revealing and are plotted in Figure 14. There are a couple of anomalous years but the trend seems very clear ---- consumption was dropping prior to the legislation which allowed amateurs to distil spirits for their own use (1996) but was steadily rising thereafter.

Just allow N. Americans to embark on a voyage of discovery into the uncharted waters of amateur distilling and you’d find there’d be an upsurge of interest in the whole subject of spirits. The big question, of course, is whether such amateur production would cut into commercial sales? It didn’t in New Zealand. It had the opposite effect. And the more likely result would be that a hobbyist who had tried to make corn whiskey would go out and buy himself a commercial bottle to see how successful he’d been. He’d become interested in the difference between a scotch, a rye and a bourbon. Between a Cognac and an Armagnac. Between a single malt and a blended whiskey. Between a Russian vodka and one made in N. America. It is likely to stimulate sales, not reduce them.

Figure 14 New Zealand –Per capita spirits consumption



When dealing with the sale of a consumer product it is necessary to take into account human psychology, and the influences around him which affect his choice. For example, what decides a man to order bottled tap water from France when he takes his girl friend to a restaurant?

If this hypothesis has any merit then it is important to draw it to the attention of commercial distillers. We fully intend to do this. If they then subscribe to the hypothesis that amateur involvement in making an alcoholic beverage may actually increase interest in that beverage you can be sure that they'll beat a hasty path to the government's door and suggest that they should change the law toot sweet.

COSTS

The costs shown below (which are approximate) apply to Canada in the year 2001 and are in Canadian dollars with no tax added. The items which involve the most uncertainty are the brass still-head and column-to-boiler adapter, for these require fabrication by a machinist. The machinist who made these items for us thought that two hours work (@ \$50/hr.) should be sufficient, and estimated that the three purchased compression fittings (sink drain) and stock brass and copper might amount to \$50. These two items therefore total \$150.

Cabinet (vanity), 36" wide with 2 doors and 2 drawers	\$ 140
Countertop, 36" wide	\$ 87
Boiler (25 or 50 litre hot water heater)	\$ 140
Glass for column, 38 mm o.d. and 4' long	\$ 20
Brass still-head and boiler/column adapter	\$ 150
Cooling coil, 16' of 3/16" copper tubing	\$ 14
Digital thermometer (mercury/glass thermometer, \$10)	\$ 65
Ball valve (3/4") for boiler, needle valve for still-head	\$ 20
Replacement element for boiler (if needed)	\$ 20
Miscellaneous, e.g. column insulation, cooling water connection, stainless steel packing	\$ 20
Total: Cabinet mounted:	\$ 676
Wall mounted:	\$ 449

FUTURE DEVELOPMENTS

In this book we have described the principles which must be followed in designing a reflux still and have shown several examples ---- from a small laboratory glass still using a Vigreux column to the much larger carriage still suitable for the home production of spirits. Undoubtedly you will wish to develop your own ideas, and there is plenty of room for improvement, so to start the ball rolling we'll discuss a few possibilities below.

The boiler.

A commercial hot water heater is difficult to beat for price, appearance and convenience, but a wish-list would include the following:

- a). A dish-shaped bottom with a drain outlet in the centre so that the boiler could be completely drained of its contents after a distillation run. As it stands at present it is necessary to tilt the boiler to empty it completely, or flush with a lot of water to avoid stale stillage sitting in the bottom.
- b). An access port on the top large enough to accept a basket or muslin bag containing plant material. This would enable the boiler to be used for the steam distillation of botanicals and production of essential oils.
- c). A larger opening than $\frac{3}{4}$ -inch for the connection to the base of the column. The $\frac{3}{4}$ -inch pipe connection constitutes a bottleneck at present, and while this is not a serious problem it would be better if it had the same diameter as the internal diameter of the column.
- d). Two heating elements, each of 1000 watts. A simple switching system would then provide 500, 1,000 and 2,000 watts. This would be cheaper than a variable transformer.

Automatic switch-off

The procedures described in this book and previous books in the series requires the distiller to be present at the end of a run in order to switch off manually. It would be much more convenient if the end of a run could be detected with a sensor and the boiler (and perhaps also the cooling water) switched off automatically.

During the first stage of beer stripping such an automatic cut-off would be comparatively simple to arrange because there is no sharp end-point, and if the boiler is left on a few minutes longer than necessary no harm is done. But in the second stage it is necessary to switch off before the end-point or the product will be contaminated with tails. To avoid this we have suggested switching receivers towards the end so that only the last receiver is contaminated.

For the beer stripping stage a simple bimetallic cut-off similar to those used in electric kettles could be installed at the top of the column. When the vapour temperature reached the set-point, e.g. 98 °C., the apparatus would switch off. It would, however, be useful to be able to vary this set-point by a few degrees because, with the different reflux ratios you may select, the temperature where beer stripping has reached the point of diminishing returns will change somewhat.

For the second stage of high-purity distillation the vapour temperature remains constant right up to the point where tails begin to appear, so to avoid having tails contaminate the product it would be necessary to place the sensor below the top of the packing in the column. In this way the sensor would detect the change of composition from pure 95% ethyl alcohol to tails ahead of time and in sufficient time to terminate the distillation. The sensor would need to be very sensitive, however, detecting changes as little as 0.1° C. if it were to do its job properly. Also, because the boiling point of ethanol varies with atmospheric pressure, it would be necessary to be able to adjust the set-point to the B.P. of the ethanol azeotrope on that particular day. Otherwise, if a cold front moved across your region, you'd have a problem.

No attempt will be made to suggest the type of instrumentation you would need for the above. We leave that to you electronic whiz-kids.

Cooling

There are a couple of disadvantages to the use of tap water for condensing alcohol vapour in the still-head. One is that you use a lot of water and the other is that you need a drain. This makes it difficult to locate your still in the garden shed or in your bedroom.

Another cooling medium, always in plentiful supply, is air. This is how we drain off the considerable heat generated by an automobile engine so there's no reason why we shouldn't use the same principle for our still. All we need is a radiator, a fan, and a pump circulating water through the cooling coil in the still. We are currently working on this.

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e-mail: strand@partyman.se

Appendix I

Effect of atmospheric pressure on boiling points

The boiling points of liquids quoted in reference books refer to the values measured at a standard atmospheric pressure of 760 mm mercury. As we all know, atmospheric pressure changes, varying considerably from day-to-day as weather patterns change and cold or warm fronts cross the region. Atmospheric pressure also changes with elevation. Not everyone lives at sea level under a stable air pressure of 760 mm Hg so the following table will allow you to interpret any temperature readings you might get in terms of ambient atmospheric conditions.

Pressure					Elevation Feet	Boiling point	
psi	mm Hg	inches Hg	kPa	millibars		Ethanol °C.	Water °C
16.5	853	33.6	113.7	1137	- 3280	81.5	103.3
15.6	806	31.8	107.5	1075	- 1640	79.9	101.7
14.7	760	29.9	101.3	1013	Sea level	78.4	100.0
13.9	716	28.2	95.4	954	1640	77.0	98.3
13.0	674	26.5	89.8	898	3281	75.6	96.7
12.3	634	25.0	84.5	845	4921	74.2	95.0

Not too many of us live below sea level but quite a few must live at elevations of several thousand feet, and it will be seen from the above table that the effect on the boiling point of ethanol is far from trivial. The same holds true of changes in atmospheric pressure at a fixed elevation, due in this case to the movement of air masses.

You will recall from the discussion of temperature changes during fractional distillation that, after the column has reached equilibrium, the heads are bled off until the temperature remains constant, indicating that pure ethanol is now distilling over. Clearly, to avoid being misled, it is useful to have some idea of what the boiling point of pure ethanol is on that particular day. The table will help in this regard.

Appendix II

Latent heat of vaporization

In order to know how much pure alcohol can be produced per minute or per hour by a 750 watt immersion heater we first need to know the rate at which the alcohol in the boiler is being vaporized and condensed in the stillhead, i.e. the boil-up rate. When we know this volume we take 10 percent of it. That is the amount we can draw off and put into our martinis.

As discussed in the text, there are two methods of determining the rate of vaporization from the boiler --- by direct measurement and by calculation. The calculation method is outlined below.

The rate at which liquid is vaporized is dependent upon two quantities; a) the energy input to the boiler, and b) the latent heat of vaporization of the liquid in the boiler (LHV). The LHV is the amount of energy required to convert a boiling liquid into vapour at the same temperature, and it is a surprisingly large quantity. The reason why energy is required to convert a boiling liquid into vapour without any rise in temperature is that molecules in a liquid are much more closely packed than in a vapour, and to convert one into the other the molecules must be wrenched away from the clutches of their fellows and push against the atmosphere. It takes energy to do this.

The energy required to vaporize water, i.e. the latent heat of vaporization (LHV), is 540 calories per gram. For ethyl alcohol the energy required is 220 calories per gram, the lower value being a reflection of its greater volatility. The composition we are involved with is 95% alcohol w/w. Simple arithmetic gives 236 calories per gram for the LHV of the 95% w/w alcohol azeotrope.

Why, you might ask, are we concerned with the energy required to vaporize 95% alcohol when we know very well that the contents of the boiler are mostly water and this water is being vaporized along with the alcohol? The explanation is this: 95% of the water vapour going up the column, carrying with it its latent heat of vaporization, is condensed in the column by the descending flow of liquid from the stillhead. The 5% water which does get through only does so because it is associated with ethyl alcohol in the azeotrope. When the 95% water condenses in the column it gives up its energy, this energy being known as the latent heat of condensation (LHC). It has the same value as the latent heat of vaporization. Therefore, the only energy escaping into the stillhead is the latent heat contained in the 95% alcohol and the 5% water. That's all there is in the stillhead and all that is being condensed by the cooling coil. Most of the water never gets there.

It is known that 860,000 calories/hour = 1 kilowatt. Therefore 860 calories/hour = one watt and 236 calories/hour = 0.27 watt

What this means is that 0.27 watts of electric power are required to vaporize 1 gram of a 95% alcohol/water mixture in one hour, so 750 watts would vaporize 2778 g/hr. or 46 g/minute. Ethanol having a S.G. of 0.8 the volumetric figure for the total reflux rate is 58 ml/minute.

When we measured the rate of reflux at total reflux with 750 watts input to the boiler we found a value of 45 ml per minute. This is less than the calculated value of 58 ml per minute because of heat loss due to imperfect insulation. This loss is equivalent to 168 watts.

If you cannot or do not wish to measure the rate of reflux yourself, you could use our figure of 45 ml. The insulation used for your boiler and column may be better or worse than ours, but is unlikely to differ very much, so you'd be pretty safe to use this figure of 45 ml.. This would mean that you could draw off 10% of this, or 4.5 ml per minute, as usable alcohol. This is particularly true since the reflux ratio of 10:1 is not critical anyway.

A footnote to this discussion is that the rate of reflux does not change during the course of a distillation, even though alcohol is steadily leaving the boiler and changing the composition and the boiling point of the liquid in the boiler. The composition of alcohol vapour in the stillhead remains constant from the time the heads are finished until the arrival of the tails, and that's all that matters; the composition of the liquid in the boiler is irrelevant.

Appendix III

Cooling water requirements

A number of people have expressed concern about the volume of cooling water required to condense the vapour from a 750 watt heater operating over many hours. It is not all that great, but if water is scarce or expensive where you live you will be interested in the following calculations.

The calculations cannot be exact because there are many imponderables. For example, the temperature of the cooling water, the permitted rise of cooling water temperature, the desired drop in the temperature of condensed alcohol, the rate of heat transfer between the cooling water and the alcohol (affected by thermal conductivity of coil material, e.g. copper, stainless steel, glass, and the thickness of the coil walls), so please read the following with these things in mind.

We are going to assume the following: The cooling water enters the coil at 10° C. and leaves it at 30° C., a 20° rise in temperature. By increasing the flow of cooling water you could decrease this rise in temperature, and by accepting a greater temperature rise you could reduce the flow of water. We also assume that the alcohol vapour is condensed in the stillhead and, following condensation, is cooled from 78.1° C. to 68.1° C., a drop of 10° C., before withdrawal.

The cooling water in the stillhead is condensing 45 g/min of a 95% w/w alcohol-water mixture (see Appendix II). The latent heat of this mixture is such that 10,856 calories per minute of energy must be drained off by the cooling water. The latent heat of vaporization of the cooling water is not involved, only its sensible heat, and this is 1 calorie per gram per degree C., the specific heat of water. So, just to condense the vapour without changing its temperature we require 10860 grams of water per degree C. per minute. Let's call it 10 litres. The collection of alcohol from a particular run will occupy (let's say) 20 hours. So the number of litres of cooling water would be $20 \times 60 \times 10 \text{ litre} = 12,000 \text{ litres}$. This is just to condense the alcohol, not cool it. If we decrease cooling water flow so that its temperature rises, not by 1° C. but by 20° C. then the volume of water would be reduced to $12,000 \div 20 = 600 \text{ litres}$.

You might wonder why the still-head doesn't cool the alcohol to room temperature. It is a matter of experience that, using the type of stillhead with cooling coil described in this book the alcohol vapour condenses on the lower turns of the coil, turns into liquid, and immediately drops off, avoiding further cooling. It is so hot, in fact, that some people suggest cooling it further by having the condensed liquid flow through a secondary heat exchanger before dropping into the collection bottle. Otherwise, they say, a lot of alcohol will be lost by evaporation. There is some truth in this but we have found it sufficient to draw off the hot alcohol and let it fall through a copper tube before entering the collection bottle. In effect, this is an air-cooled condenser.

We have calculated that 600 litres of cooling water are required just to condense the vapour. Now let us assume that the condensed liquid, before dropping off the bottom turns of

the cooling coil, is further reduced in temperature by 10° C., i.e. from 78.1° C. to 68.1° C. This will require additional cooling water as follows:

We are concerned here with, not latent heat of condensation but the specific heat of alcohol. This varies a bit with temperature but is about 0.6 calories per gram per degree C. So the number of calories to be withdrawn for a 10° C. drop in temperature is:
 $10 \times 0.6 \times 46$ grams per minute = 276 g/min or 330 litres of cooling water over a 20 hour distillation period.

Therefore, $600 + 330 = 930$ litres of cooling water are required *in toto*. To this, of course, must be added the water consumed while the column is being equilibrated. And then there's the water consumed during beer stripping. Whether or not you consider this a lot of water depends on your particular circumstances. If you feel it is a lot then you might wish to try air cooling by circulating the cooling water through a car radiator and blowing air through it. This would also avoid the need for a drain. We discuss this in the chapter on future developments.

Appendix IV

Preparing a Gin Essence

In the book “Making Gin & Vodka” (3) there is a description of the little pot still used for steam-distilling various botanicals to give a pungent essence which, when added to vodka, converts it into gin. A recipe for the type and amount of each botanical is given, but the following recipe, while similar, is a little better. It was kindly provided by Ian Smiley(5).

905 ml / 285 grams.....juniper berries
15 seeds..... white cardamom
1 ¼ tsp..... orris root
1 ¼ tsp ground coriander
zest of lemon peel..... 1/4 lemon. Just the yellow zest
2 ¼ litres of pure water

Crush the juniper berries in a blender.

Split the cardamom seeds open and discard the shells, only using the insides.

Carefully carve the yellow zest from ¼ lemon, meticulously avoiding the white pith. This pith will impart a bad flavour.

Place all ingredients in a 5 litre flask of the botanical still (see Fig. 2 in the present book for the type of still to use) and bring to the boil. When it comes to the boil, switch off and swirl, letting it steep for 45 minutes.

Swirl and bring to the boil again, reducing heat to simmer

Collect the first 375 ml of distillate and place in a bottle marked #1

Collect the second 375 ml and place in a bottle marked #2.

Switch off. Distillation complete. Add 375 ml of 96% ethyl alcohol to each bottle. This will dissolve the oily drops in the bottle (the essential oils) and also act as a preservative.

Notes.

It is best if the juniper berries are fairly fresh. They may sit around in a health-food store for years and lose much of their flavour. Buy them when the store has just stocked up.

To make the gin, add 15 ml of the essence in bottle #1 to 1 litre of 40% alcohol (vodka). With bottle #2 you'll need 20 ml of essence to provide the same degree of flavour. Quality-wise there's not much to choose between them.

Between bottles #1 and #2 there's enough essence to flavour about 45 litres of gin.

Appendix V

The Question of Legality

This chapter is written specifically for those readers who live in countries where it is currently illegal for amateurs to make their own home-made spirits. This means almost all of us. It is also written for government officials, politicians, law enforcement agencies, the news media and any advocacy groups with an influence on public policy.

The conflict between governments and moonshiners has been going on for centuries and the reasons are not hard to find. From the government point of view alcohol in one form or another is in such demand that it can be heavily taxed without fear of killing the goose that lays the golden egg. From the moonshiner's or smuggler's point of view the spread between the cost of manufacture of alcohol and cost to the consumer after tax is so great that the incentive to circumvent the law is considerable. This incentive grows greater and greater with each tax hike until a point is reached where people are driven by taxation policy to smuggle liquor or make their own, the net result being that tax revenues actually decrease while crime is encouraged.

The dollar figures involved are informative. When alcohol is made on a large scale, as it is for the fuel-alcohol industry (gasohol) its cost of manufacture is about 25 cents per litre. This is for 100% alcohol. If diluted to the 40% commonly used for vodka, gin and other distilled spirits a litre would contain about 10 cents (U.S.) worth of alcohol. The retail price of a litre of vodka will lie somewhere between \$10 and \$20 depending on the country and level of taxation. The mark-up is enormous. To be fair, some of the difference is due to the scale of manufacture, the purity of the product, transportation, the profit margin, etc., but even allowing for these factors the tax burden on the consumer is extremely high. In an attempt to justify their actions and to persuade consumers to accept them, governments promote the idea that drinking is not only sinful but harmful to your health, so (they say) the tax is made deliberately high in order to protect you! As Scrooge would say, "Bah, humbug"

In light of the above, is it any wonder that an unscrupulous operator will attempt to sell his alcohol direct to the consumer, perhaps at half the normal retail price which would still give him a very handsome profit? Or is it any wonder that the authorities crack down hard on anyone attempting to interfere with their huge source of revenue, their milch cow?

This battle between the law enforcement agencies (the good guys) and the smugglers and bootleggers (the bad guys) has been a perfect subject for stories and movies, and one which turned into real life drama during Prohibition in the United States in the 1920's. Police and gangsters fought it out with bullets, bombs and bloody mayhem, one gang slaughtering another to gain control of the market, and while all this was going on the law-abiding citizens of the world sat on the sidelines, took it all to heart and shivered in their shoes. The average person is now convinced that the production of spirits is inherently evil, something to be tightly controlled by the authorities or blood will run in the streets.

Beer and wine do not suffer from such a bad press. Being of a philosophical turn of mind the author has speculated on the underlying reasons for this. One reason may be that beer and wine-making are traditional activities and therefore hallowed by tradition. It is an activity which poets and shepherds and decent country folk might engage in as they play their flutes and dance around the Maypole. Distilling, by contrast, invokes an image of unholy forces at work --- alchemists and necromancers. Or the satanic mills of industry and the callous face of science.

A more prosaic reason based on dollars and cents is that it would be uneconomical for smugglers and bootleggers to transport a lot of water. So they concentrate the alcohol by distilling it and thereby reduce the weight and volume 8-fold. In this way much more can be loaded into a ship or truck.

Unfortunately, the “wickedness” of home distilling is now so ingrained in the social psyche that this alone is enough deterrent to make many law-abiding citizens not only refuse to engage in it but even to discuss it. We have experienced this revulsion personally. Thus, it has become self-policing.

Amateur distillation.

It is understandable why a government would wish to put a stop to smuggling and moonshining for commercial purposes, that is to say in order to sell the product and avoid the payment of taxes, but why would there be a complete ban on distillation by amateurs, on a small scale and for their own use? And why, commercially, should a distilled spirit attract a higher tax per unit of alcohol? At the risk of being tediously repetitious it is worth reminding ourselves again that distillation is one of the most innocuous activities imaginable. Unlike beer- and wine-making it doesn't produce a drop of alcohol. Not a drop. What it does is take the beer which you have quite legally made by fermentation and remove all the noxious, poisonous substances which appear inevitably as by-products in all fermentations. Strange really that the purification of a legal beverage by removing the poisons is illegal. Instead of prohibiting it, the authorities should really be encouraging distillation by amateurs. And the general public, which is so rightly health-conscious these days, would be more than justified in demanding the right to do so.

Governments surely wouldn't do something without reason would they!! There must be a reason for the ban on amateur distillation. Surely! In attempting to find this reason the first thing which comes to mind is the potential loss of tax revenue. After all, if everyone started making their own spirits at home the loss of revenue might be considerable. However, this cannot be the real reason because the home production of beer and wine for one's own use is legal, and both are taxable when sold commercially, so the authorities must not be all that concerned about the loss of revenue when people make their own alcoholic beverages.

A possible, and somewhat cynical, explanation for the prohibition of home distilling is based on the following reasoning. Home-made beer and wine are often a bit inferior to a good commercial product, and their preparation takes quite a bit of time, so only the most enthusiastic amateurs will go to all that trouble. Consequently there is no real threat to the sale of commercial products nor to the revenues generated by taxation. If, however, home distillation

were permitted, every Tom, Dick and Harriette would be in a position to make a gin or vodka which was every bit as good as the finest commercial product on the market, and could make it in quantity in a short time. This could, it might be argued, make serious inroads into commercial sales and into government revenues.

Further thought, however, makes it very unlikely that amateur production of spirits would have any appreciable effect on commercial sales. For one thing the equipment is moderately expensive (several hundred dollars) and it is necessary to follow directions rather carefully when using it so it is unlikely that the practice would ever become really widespread. Moreover, many people prefer scotch, rye, rum, etc. to either gin or vodka and it is only these two which can be made by amateurs with a quality approaching that of commercial brands. So if distillation were legalized for amateurs it would probably become nothing more than an interesting hobby, just like making wine, and offer little competition to commercial producers.

No, we have to look deeper than this in our search for a reason why governments have such a hang-up about distillation. You see, it is not just amateurs who are penalized. Commercial producers also feel the heavy hand of government prejudice and disapproval. This is illustrated by several restrictions which apply in many countries. One is the fact that the advertising of beer and wine on television is permitted whereas the advertising of distilled spirits is prohibited. Another concerns the tax imposed on distilled alcoholic products --- per unit of alcohol the tax on spirits is much higher than it is on beer and wine. A third restriction on spirits can be seen in the alcoholic beverage section in the supermarkets of some countries ---- beer and wine may be sold, and possibly fortified wines such as vermouth, but raise the alcohol concentration to 40% and the ancient shibboleth of 'hard spirits' comes into play. This is grossly unfair discrimination and naturally of great concern to distillers. As they point out over and over again, in advertisements and representations to governments, a glass of gin & tonic, a glass of wine, and a bottle of beer all contain similar amounts of alcohol, so it is inequitable to tax their product at a higher level.

So why is there this blatant discrimination on the part of governments which pride themselves on being non-discriminatory when it comes to race, religion, colour, gender, age and so on and so forth? Irrational attitudes are always difficult to deal with but in order to reform the law we have to deal with it, and this requires that we try to understand the thinking behind it. The drug involved is ethyl alcohol, C_2H_5OH , an acknowledged mood-modifier, and it is this drug which governments seek to control, but the alcohol in beer, wine and gin are identical and imbibed in similar quantities will have identical effects in terms of mood modification. So why are they taxed differently?

The only explanation which seems to fit the facts is that governments and their officials cannot understand the difference between concentration and amount. As a matter of fact quite a lot of people have this difficulty. Just because beer contains 5% alcohol whereas spirits contain 40% does not mean that the gin-drinker is 8 times more likely to over-indulge than the beer-drinker. To believe this is to be naïve. The fact of the matter is that anti-social behaviour such as hooliganism at sporting events is almost invariably caused by beer drinkers. And many studies of drinking and driving have shown that the vast majority of those pulled over have been drinking beer, not spirits. Usually they are young men who happen to prefer beer to a vodka

martini with a twist of lemon. And after the first beer they'll have another, and another, always drinking 5% alcohol but increasing the amount with each can. The 5% alcohol content is comparatively low but this is irrelevant when you drink one can after another. It is not the alcohol concentration which is the issue here, it is the amount of alcohol.

An attempt has been made by the author to bring this rather simple point to the attention of officials in the Customs & Excise Branch but the argument falls on deaf ears. We pointed out that alcohol is made by fermentation and that amateurs are allowed to make as much as they like within reason for their own use. So why not allow them to distil it? We pointed out that distillation doesn't make alcohol, it merely purifies it. Ah, is the reply, but it makes it stronger. So we're back into the confusion surrounding concentration and amount. When all else fails, the hoary old argument about amateurs poisoning themselves and going blind is trotted out. Really!

The above discussion has been argued at some length because it is important for the reader to feel comfortable with the "moral" aspects of distillation and with the supposed dangers to health. There is no need for him to be furtive about it or feel like some sort of back alley abortionist. The so-called "offence" has no moral dimension to it. It is not sinful. But it is necessary to illustrate the difficulties which would be encountered in any attempt to change the law. There would be no point in approaching government officials who may be sympathetic to the arguments but are powerless to do anything about it. No, it would be necessary to first air the subject in the news media to get the public (the voters) up to speed and then work through politicians. The approach could be based upon two issues, both of which are important to many people nowadays. One is the question of health --- governments should respond favorably to any suggestion which will lead to more healthy drinking habits (and make no mistake about it, gin and vodka are much less harmful to health than beer and wine). The other concerns our basic rights and freedoms --- it should be an absolute right for anyone to remove the poisonous substances from a legally produced beverage (beer) in order to produce another legal beverage (vodka).

The Author

The author has his Ph.D. in physical chemistry from the University of London, England and has published over seventy scientific papers. These have largely been concerned with the chemistry of plant materials, the internal structure of the plant cell wall and the structure of membranes. Applied research concerned the production of fuel alcohol from agricultural and forest residues.

Before retiring he was the Director of the Forest products Laboratory in Ottawa and the Director of Research Services at the University of Ottawa. He is now spending his retirement years in a small village in eastern Canada on the shores of The Lake of Two Mountains.

His interest in the theory and practice of small-scale distillation of alcohol stemmed from a botched attempt at making wine many years ago. It was so awful that it should have been poured down the drain. However, he decided to try and recover the alcohol by distillation and found to his chagrin that it was not as simple as it seemed. This book, like its predecessors, is the result.