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Test results on kerosene and other stoves

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Prepared for the
Energy Assessment Division
Energy Department
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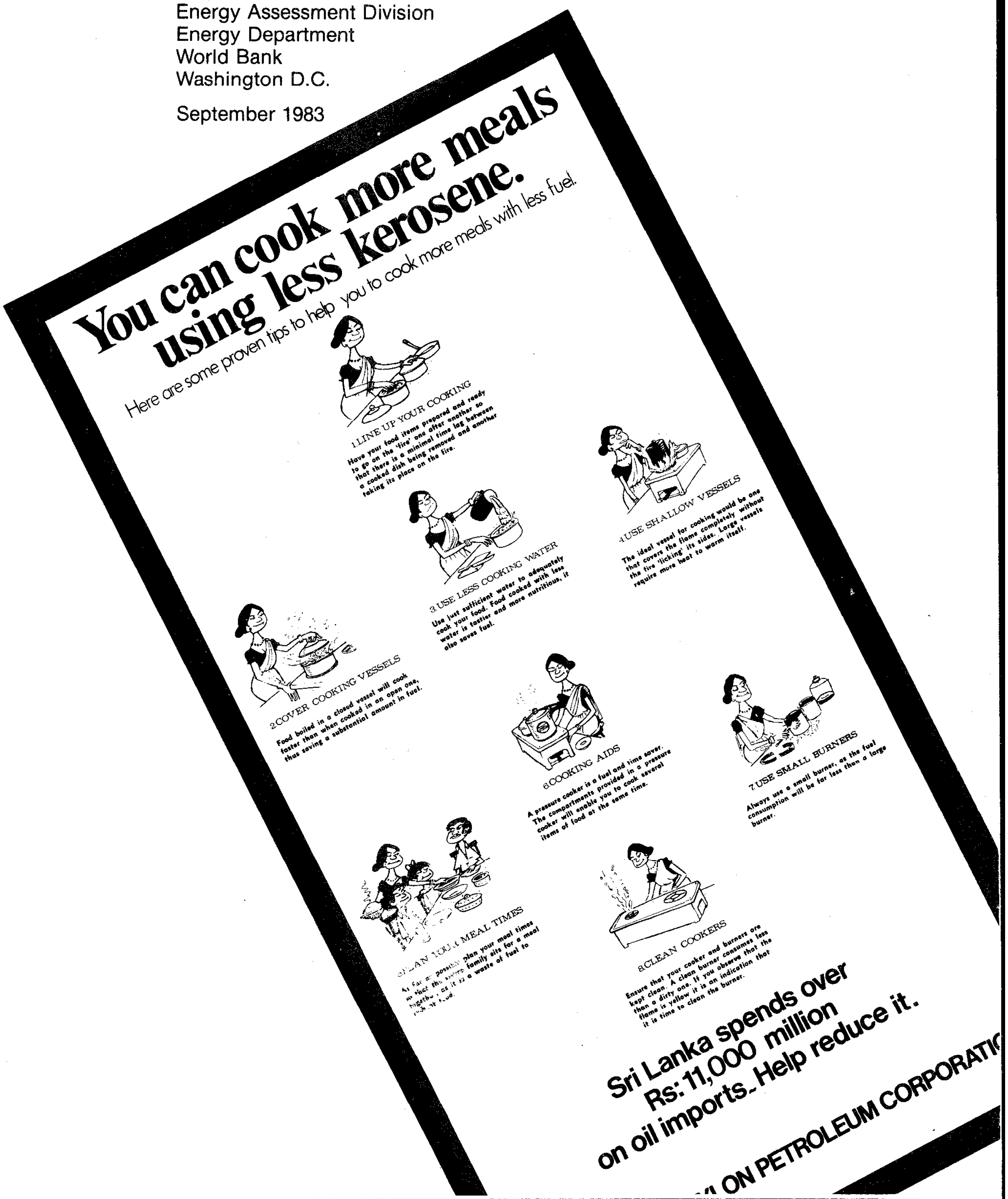

TEST RESULTS ON KEROSENE AND OTHER STOVES

By
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A Report from the

Woodburning Stove Group
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A work of this type can not be accomplished in a short time without being actively aided and abetted by others. While four of us were nearest to the work, other members of the Woodburning Stove Group at Eindhoven participated in it. We would like to specially thank Piet Verhaart for not only sharing his insights into the workings of a kerosene burner with us but also contributing a chapter to this report. Cor Nieuwvelt provided invaluable help by way of discussions, administrative support and his insistence on good quality of photographs (which somehow eluded us however much we tried!). In addition he provided an express translation service for the Tschinkel & Tschinkel paper. We are grateful for his efforts. We thank the entire group for getting into the act of stove selection for testing.

The work would have never been done without the enthusiastic support of our stove buyers. We are deeply indebted to CDP (Consultants for mangament of Development Projects) at Utrecht for the efficient way they procured over 20 stoves from several countries. We are very grateful to Erik Kijne (CDP) for taking the time out while on a busy travelling schedule in South Asia to hunt out for the stoves. We gratefully acknowledge the assistance of Willem Floor (3 stoves from Yemen), Eric Ferguson (2 stoves from Thailand) and Mr J. Pasaribu of Medan, Indonesia (1 stove from Indonesia) in broadening our choice of stoves.

Finally, our affectionate thanks to Els van der Steen and Hannie de Coster who produced an orderly type script from arbitrary bits of paper handed over to them at arbitrary times in an arbitrary order.

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FOREWORD

Ken Newcombe
Energy Assessment Division
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In the course of Energy Sector Assessments, staff of the Energy Department frequently estimate the comparative economic value of household cooking fuels. However, with the experience of over 30 country energy sector assessments, it is clear that little of substance was known about the efficiency and fuel economy of cooking with petroleum fuels in the developing countries. Kerosene and, to a lesser extent, LPG are in use in most urban areas, and even in some populous rural areas in countries. However, the great majority of the research on cooking efficiency has, to date, been focussed on wood and charcoal stoves, and even here there has been considerable confusion about the measure and meaning of efficiency.

In contracting the Woodburning Stove Group at Eindhoven University of Technology to test a number of commonly used kerosene and gas stoves, The Bank hoped to obtain a better understanding of the range of efficiency applicable to each stove type, and of the sources of variability in these data. The outcome was to be a data set which could be applied with confidence to the analysis of comparative economic value of all commonly used household fuels.

During the required laboratory work, a great deal of useful information was gathered, though rather than generating reassurance, the general conclusion is that there is a need for considerable caution in applying cooking efficiency data in economic and policy analyses, for efficiency measures per se are very much second best measures of the potential benefits of fuel saving stoves, and of the comparative advantage of one stove over another in this respect. Nevertheless, it appears that in the absence of any other readily accessible indicator of fuel economy, we have to live with this crude parameter, though wherever a significant change in policy is suggested following the application of efficiency data in this way, resort should be taken to more rigorous (and regrettably tedious) measures of fuel economy, such as the specific consumption index, in the target communities.

Of the more specific outcomes, this report confirms that quite dramatic changes in efficiency occur with such common variables as pot size and user wick setting, and that the turn down ratio (the ratio between the highest and lowest stable heat rate) of the stove has a large impact on fuel economy. However, to add to the confusion, it is also demonstrated that there is as much variation in combustion and heat transfer efficiency amongst stoves of the same general design and appearance, though from different manufacturers, as there is between stove types (for example, wick-type versus pressure kerosene stoves). Some of the sources of this variation are identified; for example it is now possible:

(a) to provide advice to governments on guidelines for the import or local manufacture of kerosene and gas stoves, and
(b) to offer simple guidance to consumers on the efficient use of kerosene stoves, with useful prospect of substantial fuel savings on a national basis.

Even so there is still much to be learnt on specific design parameters that would increase the probability of considerable economic gains from the above measures. The required research and development is not likely to be expensive and could possibly be incorporated with project lending in the household fuels sub-sector.

Finally, a word of caution! Data derived from these tests are not to be considered representative of typical household use of the appliances concerned. Not only will the manner of use vary from community to community, but the manufacturer's user instructions, even if followed lead often to sub-optimal combustion efficiency. In addition, mostly new stoves were tested in the laboratory, whereas it is anticipated that combustion efficiency, and possibly heat transfer functions, decline with use, especially in the longer term, and in the absence of regular maintenance.

The next phase of kerosene and gas stove testing should, ideally, examine the efficiency and fuel economy of appliances of various ages in regular use in households in developing countries. Without the benefit of this information it is wise, for economic analyses, to adopt generally lower efficiencies than those reported here, which are for new stoves with optimised wick settings.

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SUMMARY

The report presents the results of a test programme to evaluate the performance of kerosene stoves commonly in use in the developing countries. The work was carried out at the instance of Energy Assessment Division, Energy Department of the World Bank. The main purpose of the work was to provide reliable data on kerosene stoves of diverse designs as an aid to policy planners for selection of designs. It represents a total of three man months of effort.

An introductory chapter reviews the currently known results of efficiencies of kerosene stoves of different designs. In particular the data available are shown to be in conflict with each other. On the basis of the available documentation, it is quite difficult to resolve these conflicts. Thus there appears to be a prima facie case for carrying out detailed tests on several stove designs which hopefully will provide a better picture of the existing situation.

At the outset the principles of operation of kerosene stoves of two principal types - the wick and pressure type - are discussed briefly to lay the foundations for proper testing.

Forty three stoves from different countries, mostly from South Asia, were procured. Because of constraints of time, a selection of stoves for testing had to be made. The selection was based on:

(i) fuels used (kerosene, petrol, alcohol, gas);
(ii) design type (wick, pressurized);
(iii) country of manufacture/purchase; and
(iv) size.

In all 20 stoves were selected and the testing was completed for 18 stoves, while 2 failed in operation.

A detailed design description of the tested stoves with typical drawings, photographs, dimensions and a few specifications forms chapter 4.

The testing programme consisted of measuring P_{max}, P_{min} (kW), and efficiency. The first two were measured by simply letting the stoves burn through for a certain period of time and noting down the fuel weight loss periodically. The efficiency was measured by straightforward water boiling method. The pan sizes were selected on the basis of measured values of P_{max} according to the specifications suggested by the VEG standards in the Netherlands. The pans were all commercially available aluminium cylindrical pans. In order to assure accuracy, a given experiment consisted in bringing several identical water filled pans to boil. In all the tests a lid was used and the experiment was stopped at the boiling point. Certain

experiments were repeated to determine the possible influence of this method of performing experiments on efficiency. Additional tests on 2 or 3 stoves were carried out to determine the effect of power level and pan size on the efficiency.

Chapter six discusses the results obtained in the test programme. The average efficiencies, according to the present testing programme, were: 51% for the wick stoves; 60% for the pressure stoves; and 65% for the gas stoves. The two extremes were 24% for Divyajyoti (an Indian made wick stove) and 67% for Peak 1 (a camper's stove for petrol from the USA) and Camping Gaz Feu R (a gas stove from France). All these efficiencies are measured at the maximum power setting of each stove and not necessarily with the same pan size. The P_{max} values were under 2 kW for most of the stoves tested and P_{max}/P_{min} ratios covered a rather wide range between 2,8 and 8.

During the analysis of results a discrepancy was discovered between the results obtained in this test programme and manufacturer's specifications. This was traced to the difference in wick setting procedure suggested by the manufacturer and the one adopted in this investigation. Certain tests were rerun to establish the effect of this difference and it is shown that from the fuel economy point of view the wick setting procedure adopted in this investigation yields better results.

The tests with and without lids, and with and without the inclusion of boiling regime revealed no significant influence on efficiency. However, higher fuel consumption for bringing to boil is the inevitable consequence of not using a lid. The influence of power level on efficiency was rather small, while the pan sizes chosen could have a rather large influence on the efficiencies. The Lark, a wick stove made in the People's Republic of China, showed an efficiency of 61% with a 24 cm diameter cylindrical pan. This is about 50% (in a relative sense) higher than the one obtained with a 16 cm diameter pan. Thus the ordinary wick stove is capable of giving very high efficiencies provided the pan size is chosen with care.

Next detailed comparisons between the present results and those obtained by others are presented. The difficulties of doing these are discussed.

Two aspects receive special attention: (i) generalized correlations between design and performance; and (ii) fuel consumption estimates for specific cooking tasks. The correlation attempts, while not very successful, show that: (a) wick stoves on the average seem to have P_{max}/P_{min} of about 5; (b) the pressure stoves and gas stoves seem to show best performance for a power density (defined by the power level of the fire divided by the pan bottom area) value slightly smaller than 7 W/cm^2; and (c) no conclusions for the wick stoves on this basis seems possible.

The fuel consumption estimates provided in this chapter clearly demonstrate the assertion made earlier that the higher the P_{max}/P_{min}

is for a stove, the better is the fuel economy. The penalties involved by special wick setting procedure to attain these are shown to be quite modest.

The final section of the chapter provides an excercise in rating the different stoves carried out by the authors. This excercise is included in an otherwise engineering laboratory study with a view to emphasize that the fuel economy of a stove may not be the deciding factor governing the adoption of a stove by the consumers concerned.

The report ends with a concluding section whose main message is that wick stoves currently made and marketed in the developing countries, while they could be made considerably better, are reasonable kitchen equipment. This conclusion is reinforced by the price one pays for such stoves.

A series of appendices are included to make the report more or less self-sufficient. We would like to draw the attention of the reader to appendices 3 and 5 particularly. Appendix 3 provides an assessment of the accuracies of the results obtained in the work while appendix 5 describes a methodology of converting water boiling test results into fuel consumption estimates for specific cooking tasks. The method is shown to lend itself for verification by comparing its result with an actual cooking test reported from Fiji (Siwatibau, 1981).

1. INTRODUCTION

The work presented in this report arose out of a request from the Energy Assessment Division, Energy Department of the World Bank. The request was to provide reliable data on the thermal efficiency of kerosene and gas stoves commonly in use in developing countries as a guide to policy planners in stove selection.

The work consisted primarily to measure efficiencies of several stoves manufactured in different countries covering different designs using different liquid and gaseous fuels. Before carrying out efficiency tests, the maximum and minimum powers* were determined for each stove. The efficiencies were measured by simple water boiling tests.

Before proceeding further, it is useful to list the chronology of activities to lend an appropriate perspective to the work in the report. This is done in table 1.1. The total work involved roughly 3 man months of effort.

Table 1.1. Chronology of activities

Activities	Date/s
Request from the World Bank	April 5, '83
Proposal sent to the World Bank	April 14, '83
Approval from the World Bank	May 5, '83
Procurement and selection of stoves	May 15 - June 15, '83
Preliminary work (familiarization)	June 1 - June 15, '83
Testing programme	June 16 - July 20, '83
Preliminary results sent to World Bank	July 26, '83
Data analysis, repeat tests and report preparation	July 27 - Sept. 1, '83
Additional testing with one pan diameter	Nov. 24 - Dec. 5, '83

1.1. Previous work

We did not make any effort to carry out an exhaustive literature search pertaining to kerosene stoves. In our archives, two reports on rural energy studies included some test results on kerosene stoves among others. We will briefly review these below.

Siwatibau (1981) in her study on rural energy in Fiji indicated experimental results on several types of cooking stoves. The Hong Kong 10 Wick and Swedish Primus no. 1 were tested using the water boiling method. The results obtained were compared

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* See chapter 5 for the definition of power.

with the results of tests conducted by the New Zealand Consumer Council (NZCC). The comparison is presented in table 1.2. The procedure used by Siwatibau was to average two efficiencies: 'one obtained by boiling a litre of water to a temperature of 60° C and the other by carrying out the same boiling up to 100° C from ambient temperature.' The NZCC tests were stated to be as boiling 2 litres of water. The reference does not mention either the power levels or the pan sizes used in either tests. Our guess is that the two tests used different pans. Thus we would not be surprised at different values obtained in the two sets of tests. But we are surprised at the results that the Fiji tests rate the Swedish Primus no. 1 as the better one, while the NZCC tests rate the Hong Kong 10 Wick Stove as the better one. We will refrain from providing any explanation for this inversion since it would sound like speculation in the absence of real data. The report of Siwatibau does not point out the reasons for factor 2 variation in the Fiji tests. Finally, the Fiji work reported cooking test results that were consistent with their water boiling tests, again contradicting the NZCC test results of table 1.2.

Table 1.2. Comparison of test results of Siwatibau and NZCC

Stove type	Efficiencies (%)	
	Siwatibau	NZCC
Hong Kong 10 Wick	15 - 29	37,7
Swedish Primus no. 1	30 - 57	27,5

We now turn to the work of Islam (1980) on rural energy in Bangladesh. He carried out tests on wick stoves (with wick control and flow control) and two types of gas stoves among others. He used several pans of different shapes and materials, and two types of liquid fuels - kerosene and methanol. He also includes power levels of the fire used in many of his experiments. A problem with Islam's report is that some of the pan dimensions are not easy to figure out from the tabulated information. A comment that can be made on the results is that the kerosene wick stoves produce efficiencies of the order of 53 to 54% under certain conditions. We attribute this to the 5,45 kg of water used in the tests and the maximum diameter of the spherical bottom pan used, which was as large as 28 cm.

Towards the end of the preparation of this report, we came across another work, that of Tschinkel and Tschinkel (1975) in Tunisia. They carried out water boiling tests on four types of stoves: (i) pressure fed kerosene burner; (ii) wick fed kerosene burner with fixed wick (this is referred to as the flow control wick stove by Islam); and (iv) propane or butane gas burner. They used rather small pans with casserole shapes (frustrum of a cone: 1 litre capacity - bottom diameter, 15 cm, top diameter 18 cm and height 9,5 cm; 2 litre capacity - bottom diameter 16,5 cm, top diameter 20,5 cm and height 10,5 cm). Their main results are summarized in table 1.3. The range of efficiencies correspond to the range of power levels.

Table 1.3. Efficiency of stoves
(Extracted from Tschinkel & Tschinkel 1975)

Stove type	P_{max} kW*	$\frac{P_{max}}{P_{min}}$	Efficiency range %
Pressure fed kerosene burner	2,55	3,14	47 - 56
Variable wick kerosene burner	0,99	1,09	38 - 41
Fixed wick kerosene burner	2,18	1,35	31 - 38
Propane burner	1,64	4,4	47 - 61

* Throughout this report we have used SI units. Thus we have converted the original units in other references into SI units.

It is clear from the above review that the available efficiency results vary from 15 - 54% for wick stoves and 30 - 57% for pressure stoves. Part of the problem can easily be explained as due to lack of standardization of testing procedure. And we suspect that a large part of the problem lies in an inadequate appreciation of the different factors that determine the efficiency of a stove.

1.2. Plan of the report

The chapter following this presents a brief description of the principles of operation of different types of kerosene burners. Chapter 3 presents the criteria and procedures adopted for selecting the stoves that were tested. This was necessitated by the fact that we were not in at the buying scene and we could only provide a rather crude description of our requirements to the buyers. Hence more stoves were procured than could be tested in the time available. Chapter 4 provides design descriptions of the stoves selected for testing. The next chapter describes in detail the testing methodology. We have drawn freely from our experience in testing wood-stoves, the VEG standards in the Netherlands for testing gas ranges and the more recent work done on the standardization of woodstove testing at a meeting in Arlington, Virginia.

The results of the work are discussed in chapter 6. It starts with results of P_{max}, P_{max} / P_{min}, and efficiency. Various discrepancies that can arise in such work are discussed. Next the extent of influence of power level and pan sizes are studied in some detail. An additional series of tests were done on all the tested stoves with a single pan whose diameter was larger than the pans used in the previous experiments. We then present some comparisons between the results obtained in this present testing programme with the results mentioned in the previous section. This is followed by some generalized correlations involving a few stove parameters. We use next the results obtained to compute fuel consumption for a specific class of cooking tasks for different stove types. Lastly, a bird's eye view of the quality of stoves as a desirable kitchen equipment is provided.

The concluding chapter, after a brief summary of the work, presents some engineering recommendations for improving the wick stoves and suggests a few lines of research for improving their performance.

A set of appendices are included to make the report more or less self-contained so that an interested reader could use the material in the report without extensive outside reading.

Before concluding this introduction, we should like to state that our experience in working with these stoves is quite limited and the whole work was accomplished in a very short time. Thus quite a lot of rough edges remain in it, which can only be sorted out by more work.

2. PRINCIPLES OF OPERATION OF KEROSENE STOVES*

Domestic kerosene burners can be classified into two important categories namely vapour jet burners and wick burners. The latter can again be subdivided into open wick burners and enclosed wick burners. The enclosed wick burner or range wick burner has become very popular due to its simple construction and therefore low cost as well as for its good cooking performance as borne out in this report.

2.1. Vapour jet burners

Essential is that the kerosene is available at a pressure higher than atmospheric. Stationary installations may make use of pressure resulting from the kerosene reservoir being situated at a higher level than the burner, in portable burners this is achieved by having a hermetically closed fuel container in which a small hand-pump is incorporated. With the pump air is introduced into the container which accumulates above the liquid enabling the latter to rise in the riser tube. Arriving in the hot vaporiser the kerosene evaporates and leaves through the small nozzle in a high velocity jet. In the free space between the nozzle and the flame stabilizer/holder the jet entrains a sufficient amount of ambient air to enable the mixture to burn with a blue premixed flame. There are various ways to keep the flame in the desired place. More recent developments favour a perforated cylindrical shell from which multiple small flames issue resulting in stable and practically noiseless operation.

In the old (Primus) models the impingement area of the vapour jet on the bottom of the vaporiser served as a flame holder. This gave a fluttering and very noisy flame. In general vapour jet burners give a compact and intense flame with good heat transferring capability to the pan. Having the flame holder close to the vaporiser ensures a sufficient heat supply to vaporise the incoming kerosene.

2.2. Open wick burners

The typical open wick burner has from one to three flat wicks burning with the well-known yellow flame.

For cooking purposes the pan support is situated about 10 cm above the highest point ever reached by the wicks. In this way the pan bottom does not touch any visible part of the flames ensuring clean operation. The wicks have to be turned up with care to be sure of smokeless operation. The better the quality of this kind of wick stove, the less the flame height will increase at warming up from the cold state. Even though various ingenious arrangements for channeling air to the flame were developed over the years, the power output of these burners is very low. They are eminently suitable for long simmering operations and as such still enjoy a certain popularity (be it mixed with nostalgia) in The Netherlands.

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* This section was contributed by Ir. P. Verhaart.

2.3. Range wick burner

These were developed in an effort to increase the power output of wick burners while keeping the combustion clean. The principle of construction of a range wick burner is as follows. A number of wicks are fixed in a holder such that they can be moved up and down. Moving up the wicks causes them to emerge into an annular space formed by two thin walled concentric perforated steel shells. The distance between the shells is a little more than the thickness of the wicks, usually around 12 mm. The height of the cylindrical shells is about 10 cm.

To start the stove the wicks are turned up and set alight. Through the draft created by the flames ambient air is drawn through the small holes into the annular space. Where the perforations touch the flame region small "inverted" flames of air, reacting with combustible vapours can be observed. If the wicks are turned up to a sufficient height the top level of the flames gradually rises, eventually filling the whole annular space and emerging from the open top in a stable blue flame. Through the heat generated by the reaction of air and kerosene vapour the shells after some time will glow red hot. To keep that heat from radiating away an outer cover is usually provided.

In the tests the highest power was defined as the heat production rate associated with the highest blue flame obtainable. Tests showed that having the wicks enclosed in the way described above increased the maximum heat output rate in smokeless condition a factor 3 as compared to operation with open wicks.

According to Romp (1937) the reason for the occurrence of blue flames arises from the different chemistry of this kind of combustion. In a jet of combustible vapour or gas burning in air the gas in the centre of the jet is heated to a high temperature in the absence of oxygen. Hydrocarbons will break down at that temperature giving rise to the well-known yellow flame in which incandescent carbon particles radiate light and part of that carbon may leave the flame unburned. If, on the contrary, a jet of air is fed into an environment of combustible gas or vapour, the jet of air is most intensely heated which favours "clean" chemical reactions with the hydrocarbons. It is supposed that first aldehydes are formed which in turn are further oxydised via acids and carbon monoxide to carbon dioxide and water vapour. One can certainly see that in the case of the enclosed wick burner the burning process is spread over a much larger volume than in the open wick case. The practical result is a demonstrably complete and clean combustion.

3. SELECTION OF STOVES FOR TESTING

Forty three stoves were procured from different countries, predominantly from South Asia. This emphasis was the consequence of the availability of a member of CDP* who was on a study mission, for the Dutch Minister for Development Co-operation, on the use of bio-gas plants in these countries. Table 3.1 shows the countries and the number of stoves procured from each. Appendix 1 provides the photographs of all the stoves procured, their brand names, the countries from which they were procured, and the countries in which they were manufactured. A few stoves came with descriptive leaflets provided by the manufacturer. Copies of these are included in Appendix 2. At the time of this writing the compilation of the price list is incomplete.

Table 3.1. Countries and the number of stoves procured

Country	Number of stoves
Indonesia	7
Singapore	8
India	12
Kenya	3
Yemen	3
Thailand	2
Netherlands	2
Personal sources	6

In the time available, it was impossible to test all the procured stoves. Further, a superficial examination of the stoves showed that many of them were similar in construction. Thus, to help in the process of arriving at a representative selection, a classification system was evolved. It is shown below.

Fuel: Kerosene, Butane, Propane, Petrol, Diesel, Alcohol

Design type:
- Wick (material & shape)
- Pressurized (pumped)
- Pressurized (non-pumped, i.e., no pump was incorporated into the stove proper)
- Pool burner

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* Consultants for management of Development Programmes, Utrecht, The Netherlands

Country of purchase/manufacture:
India, Malaysia, Korea, Singapore, Thailand, Soviet Union, Peoples Republic of China, Yemen, Kenya, Netherlands, Sweden, United States, France

Size: Small, medium, large

This classification system was used independently by the members of the Woodburning Stove Group of Eindhoven (seven in all) to prepare individually a list of 12 stoves to be tested. A comprehensive list of 14 stoves was constructed from these 7 lists by a straightforward polling procedure. The testers Sangen and Sielcken added 6 more to take into account some of the missing features according to the classification system from the selected 14. Table 3.2 lists all the stoves tested.

Two features of the selection need to be mentioned here. Swan 14 and Swan 20 are of the same design made by the same manufacturer, but Swan 20 is bigger than Swan 14. Similarly Prabhakar and Axe are of the same design made by different manufacturers, but of two different sizes. The same holds good for Camping Gaz Feu R and Camping Gaz Bluet. These are made by the same manufacturer and of the same design but are of different sizes. The second aspect concerns the numbering of stoves. Two numbers have been used in this report to refer to each stove. The first number is the serial number of the stove as it appears in table 3.2 and all other tabulated information occurs according to this order. The second number refers to what we call the identification number. This awkward method of referring to stoves is due to the fact that each stove got a label carrying a number as and when it arrived at the lab and our log books are maintained according to this number. In this report we have grouped stoves according to the design type - wick, pressurized, etc. Thus 10-13 means that the Prabhakar stove appears as the 10th entry in table 3.2 and was the 13th stove to receive a label in the lab.

Table 3.2. List of stoves tested

Sl.no.	Identification number	Brand name of stove	Country of Manufacture	Country of Purchase
1*	7	Ashok	M/s Ashok Iron and Steel, India	India
2	8	Nutan	Indian Oil Corp., India	India
3	11	Surya	Hero Metal Crafts, India	India
4*	12	Divyajyoti	India	India
5*	22	Hock	Indonesia	Indonesia
6**	25	Ideal	Korea	
7	6	Swan 14	?	Indonesia
8	36	Swan 20	?	Indonesia
9	35	Lark	Lark Co., Peoples Rep. of China	Yemen
10	13	Prabhakar	Ogale Industries Ltd., India	India
11	24	Axe	Lee Tai Metal Works, Malaysia	Singapore
12*	14	Primus 505	AB Optimus, Sweden	The Netherlands
13	15	Annby	Daerim Gas Co. Ltd., Korea	The Netherlands
14*	19	Primus	AB Optimus, Sweden	The Netherlands
15	38	Primus	Soviet Union	Yemen
16	16	Peak 1	The Coleman Co. Inc., USA	The Netherlands
17	18	Optimus 77A	AB Optimus, Sweden	The Netherlands
18*	20	Camping Gaz Feu R	Camping Gaz Int., France	The Netherlands
19	21	Camping Gaz Bluet	Camping Gaz Int., France	The Netherlands
20	39	Propane Burner	Japan	Thailand

Notes: * Stoves selected by the testers.
** This stove was later discovered to have a part missing and could not be operated.

4. DESCRIPTION OF STOVE DESIGNS

In the abstract, a stove for cooking or any other related task consists of five principal elements:

(a) a fuel storage facility;
(b) a fuel transport arrangement;
(c) a burner assembly;
(d) a control mechanism; and
(e) a pan support.

For stoves using liquid fuels, the customary designs integrate all these elements into a single unit. For stoves using lpg or other gases the fuel storage and transport can be separated or integrated into the stove proper. The latter are the usual campers' stoves, that can be expected to supply no more than a day's cooking energy requirements for a normal family. The former is the preferred version for supplying cooking energy at the household level. In this version the fuel could be either piped to individual households from a central storage facility with associated compressor/blower or from an individual storage bottle which can be refilled periodically (about a month or so). At the end of the report we provide estimates of refilling periods for different stove classes on the basis of cooking energy needs.

The individual design differences arise not only according to the burner power output and fuel tank capacity but also according to the manner in which the different elements are integrated into a stove. By far the most common stove employed in the developing countries appears to be the wick stove. Fig. 4.1 is a drawing of the generic form of wick stoves. Design differences can arise due to different wick shapes, airholes in the flame holder, number of screens in the flame holder, the form of the control mechanism and the dimensions. Detailed dimensions shown in the diagram are provided in the data sheets that follow this section.

Fig. 4.2 shows another type of wick stove, the fuel tank location and the control mechanism are significantly different. The transport of fuel to the burning zone is accomplished through a fixed wick. The control of power output is achieved through a needle valve located in a tube leading the fuel from the tank to the wick.

Fig. 4.3 is the classic primus stove of a conventional design, for use with kerosene while fig. 4.4 shows a similar stove but for use with petrol. Fig. 4.5 is a pool burner using alcohol (spirit) as the fuel. Fig. 4.6 is a drawing for the typical campers' stove. Fig. 4.7 is a drawing for a propane gas burner.

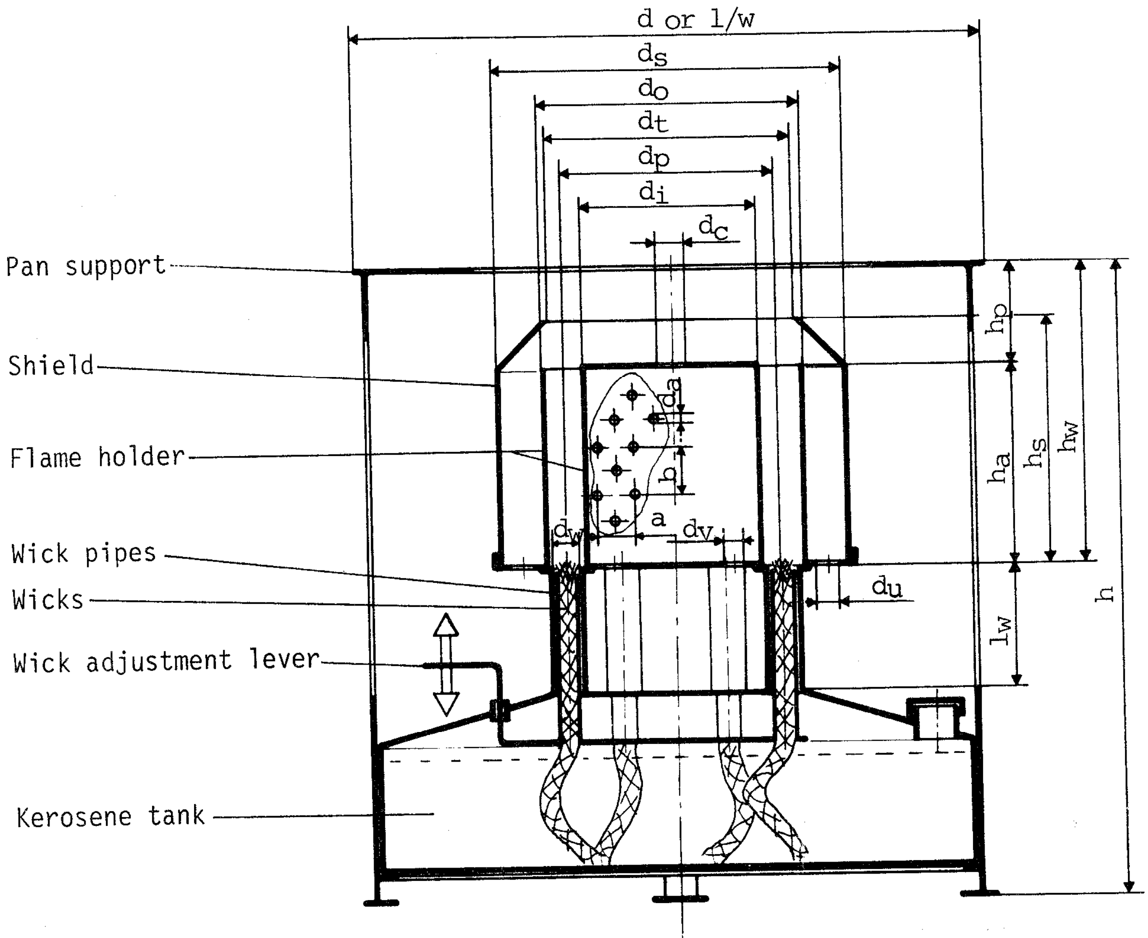


Fig. 4.1. Wick stoves with separate pan support.

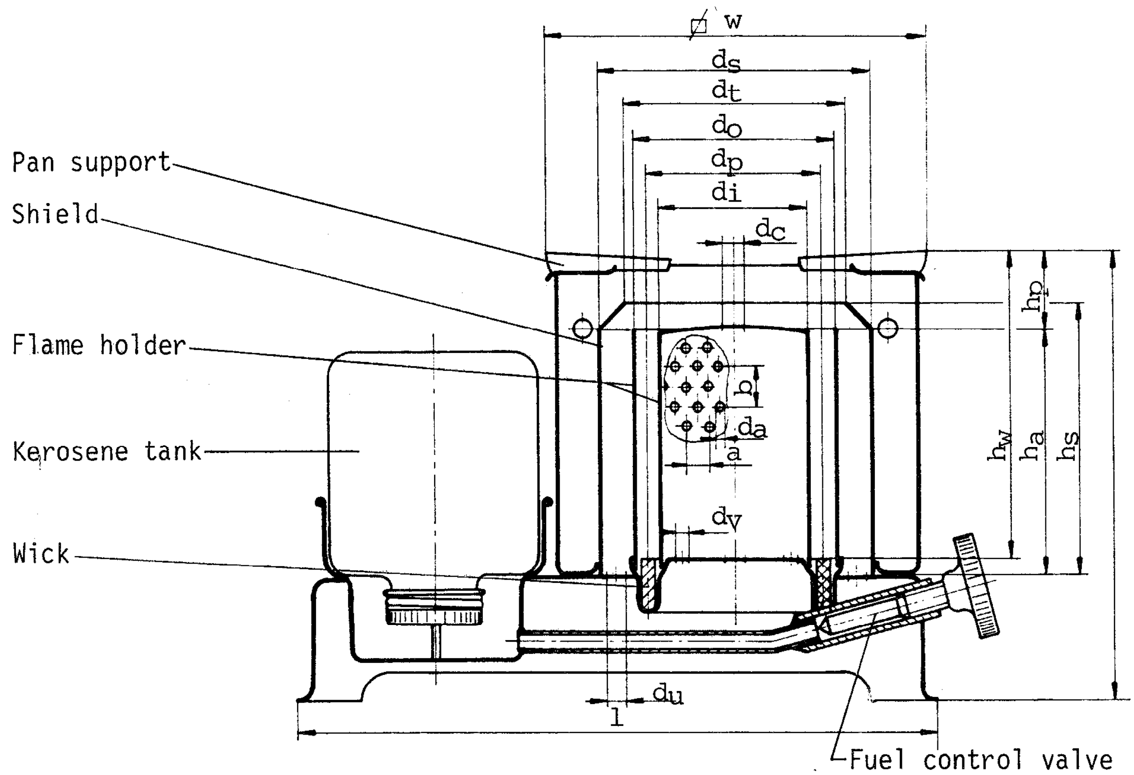


Fig. 4.2. Fixed wick stoves with fuel control valve

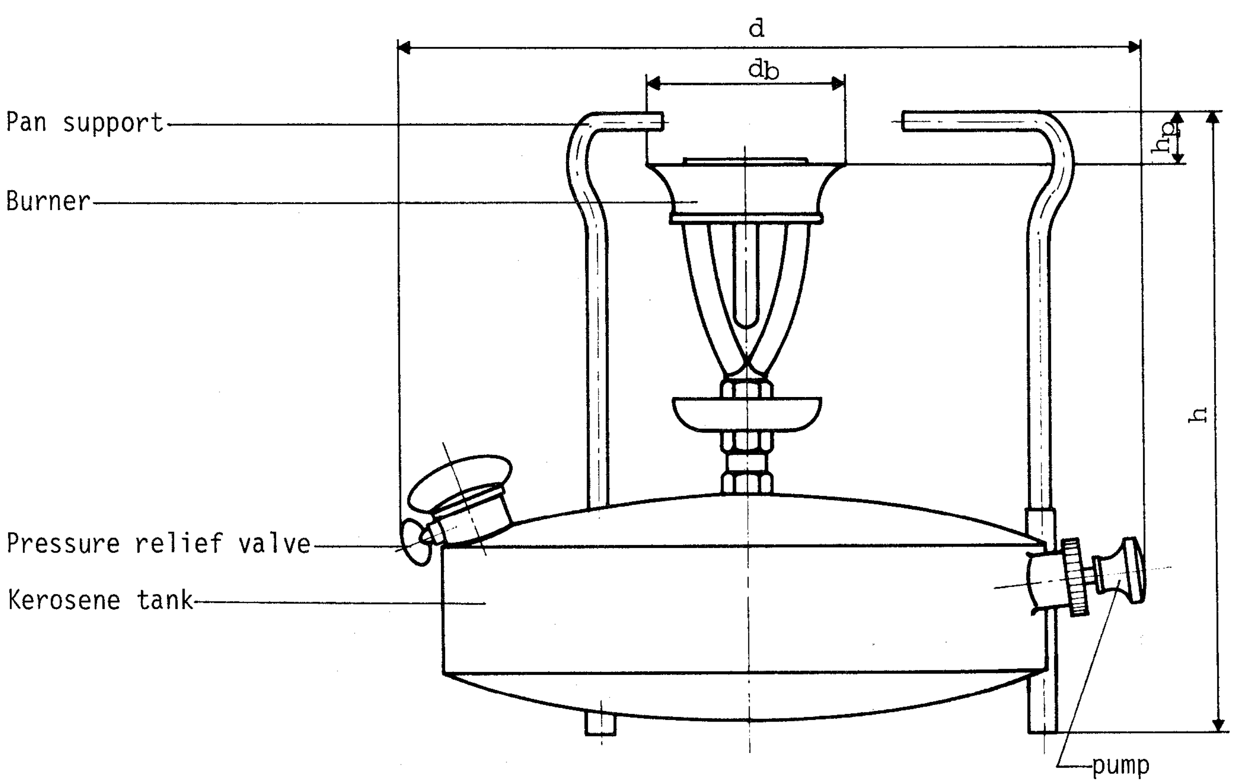


Fig. 4.3. Kerosene burner.

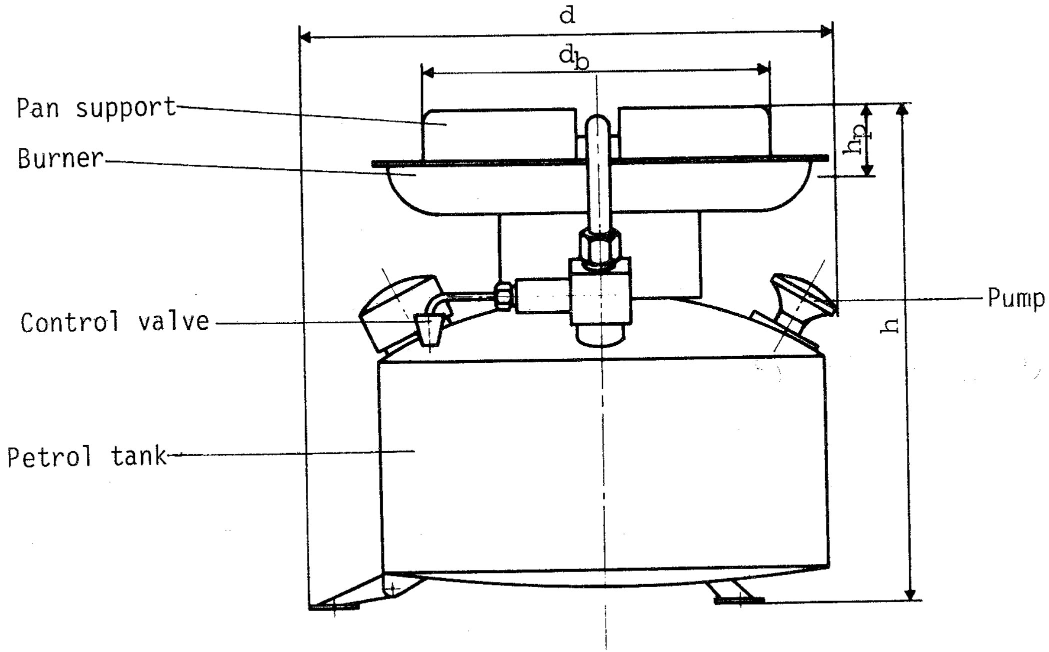


Fig. 4.4. Petrol burner.

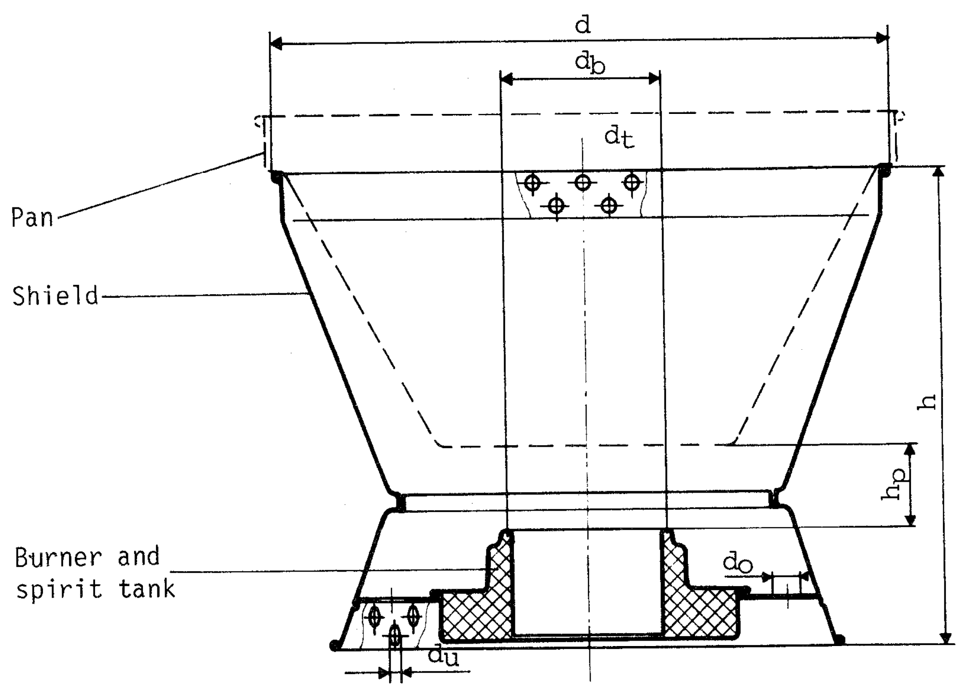


Fig. 4.5. Spirit burner with belonging pan

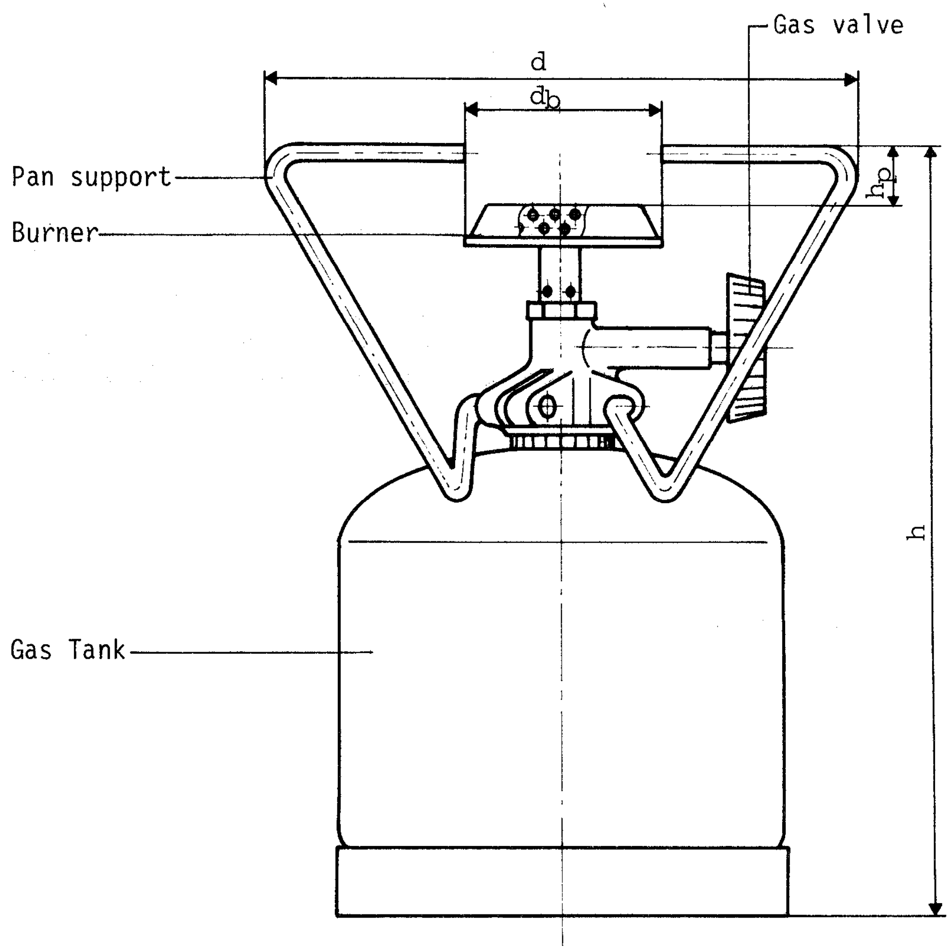


Fig. 4.6. Butane gas burner

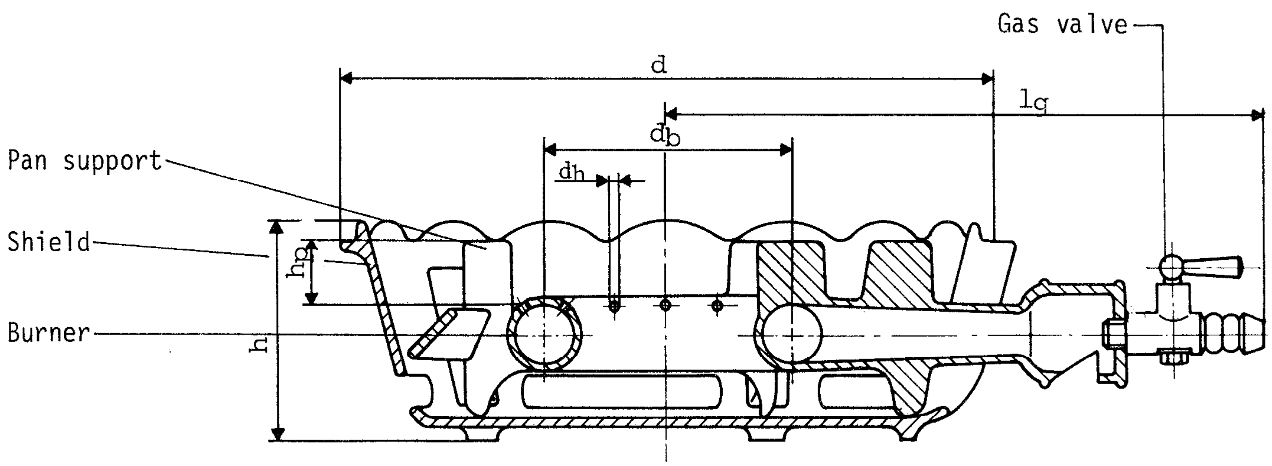


Fig. 4.7. Propane gas burner

A set of data sheets has been compiled providing detailed specifications of all the stoves tested in this programme. These data sheets include photographs of the stoves as well. The power output and efficiency figures were measured as part of this study. The efficiencies quoted in the data sheets concern only the experiments run with pan sizes selected according to VEG standards as pointed out in chapter 5. These data sheets are shown in the succeeding pages of this chapter.

Name	: Ashok
Number	: 7
Manufact./country	: Ashok Iron & Steel Fabricators/India
Country of purchase	: India
Price	: 12 ($)
Weight (empty)	: 3 (kg)
Tank capacity	: 2 (kg)
Material/finish	: Steel/painted
Wick material	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

Overall dimensions (square)	: l × w × h:			
(round)	: d × h	: 270 × 300	(mm)	
Number of wicks	: n_w	: 10		
Wick hole diameter	: d_w	: 6,8	(mm)	
Wick pitch circle	: d_p	: 90	(mm)	
Wick pipe length	: l_w	: 43	(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 77 × 122	(mm)	
(outside)	: $d_o \times h_a$	: 105 × 122	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,5	(mm)	
(outside)	: d_a	: 1,5	(mm)	
Flame holder holes pattern (inside)	: a × b	: 7 × 9	(mm)	
(outside)	: a × b	: 7 × 9	(mm)	
Central hole diameter	: d_c	: 9	(mm)	
Inside airholes (number)	: n_v	: 1		
(diameter)	: d_v	: 77	(mm)	
Outside airholes (number)	: n_u	:		1)
(diameter)	: d_u	:		
Shields (number)	: n_s	: 1		2)
(diameter × height)	: $d_s \times h_s$	: 165 × 155	(mm)	
Shield top diameter	: d_t	: 104	(mm)	
Distance wick-panbottom	: h_w	: 145	(mm)	
Distance top flame holder-panbottom	: h_p	: 23	(mm)	
Minimum power	: P_{min}	: 0,6	(kW)	
Maximum power	: P_{max}	: 2,0	(kW)	
Nominal power	: P_{nom}	: 1,9	(kW)	
Efficiency with a pan of 18 cm diameter	: η	: 48	(%)	

1) Whole ring between outside flame holder wall and shield open.
2) Shield composed of two steel sheet walls with a layer of 4 mm asbestos in between. Shield partly encloses the wick pipes.

Name	:	Nutan
Number	:	8
Manufact./country	:	Indian Oil Corp. Ltd./India
Country of purchase	:	India
Price	:	7,25 ($)
Weight (empty)	:	2,6 (kg)
Tank capacity	:	1,6 (kg)
Material/finish	:	Steel/painted
Wick material	:	Cotton
Fuel level indication	:	Yes
Fuel	:	Kerosene
Type	:	See fig.: 4.1

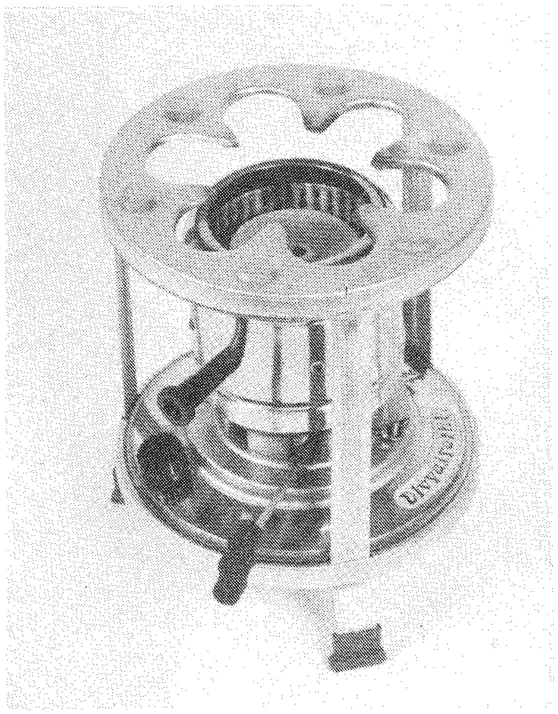
Overall dimensions (square)	: l × w × h:				
(round)	: d × h	: 265 × 235		(mm)	
Number of wicks	: n_w	: 10			
Wick hole diameter	: d_w	: 7,2		(mm)	
Wick pitch circle	: d_p	: 90		(mm)	
Wick pipe length	: l_w	: 42		(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 75 × 99		(mm)	
(outside)	: $d_o \times h_a$	: 99 × 99		(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,3		(mm)	
(outside)	: d_a	: 1,6		(mm)	
Flame holder holes pattern (inside)	: a × b	: 8 × 14		(mm)	
(outside)	: a × b	: 8 × 14		(mm)	
Central hole diameter	: d_c	:			1)
Inside airholes (number)	: n_v	: 66	4		
(diameter)	: d_v	: 1,4	2 × 37	(mm)	2)
Outside airholes (number)	: n_u	: 40			
(diameter)	: d_u	: 6		(mm)	
Shields (number)	: n_s	: 2			
(diameter × height)	: $d_s \times h_s$	: 128 × 110, 170 × 140		(mm)	3) 4)
Shield top diameter	: d_t	: 112		(mm)	
Distance wick-panbottom	: h_w	: 98			
Distance top flame holder-panbottom	: h_p	: 19			
Minimum power	: P_{min}	: 0,2		(kW)	
Maximum power	: P_{max}	: 1,1		(kW)	
Nominal power	: P_{nom}	: 1,2		(kW)	
Efficiency with a pan of 14 cm diameter	: η	: 44		(%)	

1) 67 holes of diameter = 1,6 mm. (same material as outside wall of flame holder).
2) A centre of perforated steel, with 4 slotholes at the circumference.
3) Outer shield insulated with 4 mm asbestos.
4) Inner and outer shield as one unit, the shield also encloses the wick pipes. Holes in the bottom of the annular space between the two shields. Function of these holes is not clear.

Name	: Surya
Number	: 11
Manufact./country	: Hero Metal Crafts/India
Country of purchase	: India
Price	: 4,50 ($)
Weight (empty)	: 2,3 (kg)
Tank capacity	: 1,1 (kg)
Material/finish	: Aluminium, steel/painted, chromed
Wick material	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

Overall dimensions (square)	: l × w × h:			
(round)	: $d \times h$	: 260 × 240	(mm)	
Number of wicks	: n_w	: 10		
Wick hole diameter	: d_w	: 7,5	(mm)	
Wick pitch circle	: d_p	: 7,5	(mm)	
Wick pipe length	: l_w	: 32	(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 63 × 86	(mm)	
(outside)	: $d_o \times h_a$	: 85 × 95	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,8	(mm)	
(outside)	: d_a	: 1,8	(mm)	
Flame holder holes pattern (inside)	: a × b	: 12 × 12	(mm)	
(outside)	: a × b	: 12 × 12	(mm)	
Central hole diameter	: d_c	: 8	(mm)	
Inside airholes (number)	: n_v	: 1		
(diameter)	: d_v	: 63	(mm)	
Outside airholes (number)	: n_u	: 10		
(diameter)	: d_u	: 12	(mm)	
Shields (number)	: n_s	: 2		1)
(diameter × height)	: $d_s \times h_s$	: 120 × 120, 160 × 120	(mm)	2)
Shield top diameter	: d_t	: 120	(mm)	
Distance wick-panbottom	: h_w	: 120	(mm)	
Distance top flame holder-panbottom	: h_p	: 35	(mm)	
Minimum power	: P_{min}	: 0,1	(kW)	
Maximum power	: P_{max}	: 1	(kW)	
Nominal power	: P_{nom}	:	(kW)	3)
Efficiency	: η	:	(%)	3)

1) Outer shield insulated with 4 mm asbestos.
2) Shield also encloses wick pipes. There are holes in the bottom of the annular space between the two shields. Function of these holes is not clear.
3) No efficiency tests because of bad functioning of the stove.



Name	: Divyajyoti
Number	: 12
Manufact./country	: ?/India
Country of purchase	: India
Price	: 7,50 ($)
Weight (empty)	: 2 (kg)
Tank capacity	: 0,4 (kg)
Material/finish	: Steel/galvanized
Wick material	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

Overall dimensions (square)	: $l \times w \times h$:			
(round)	: $d \times h$	: 220 × 260	(mm)	
Number of wicks	: n_w	: 6		
Wick hole diameter	: d_w	: 5 × 23	(mm)	1)
Wick pitch circle	: d_p	: 87	(mm)	
Wick pipe length	: l_w	: 35	(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 74 × 82	(mm)	
(outside)	: $d_o \times h_a$	: 100 × 94	(mm)	2)
Flame holder holes diameter (inside)	: d_a	: 2	(mm)	
(outside)	: d_a	: 2	(mm)	
Flame holder holes pattern (inside)	: $a \times b$	: 9 × 9	(mm)	
(outside)	: $a \times b$	: 9 × 9	(mm)	
Central hole diameter	: d_c	: 11	(mm)	
Inside airholes (number)	: n_v	: 6		
(diameter)	: d_v	: 8	(mm)	
Outside airholes (number)	: n_u	:		
(diameter)	: d_u	:		3)
Shields (number)	: n_s	: 1		
(diameter × height)	: $d_s \times h_s$	: 123	(mm)	2)
Shield top diameter	: d_t	: 92	(mm)	
Distance wick-panbottom	: h_w	: 137	(mm)	
Distance top flame holder-panbottom	: h_p	: 43	(mm)	
Minimum power	: P_{min}	: 0,4	(kW)	
Maximum power	: P_{max}	: 1,2	(kW)	
Nominal power	: P_{nom}	: 1,2	(kW)	
Efficiency with a pan of 16 cm diameter	: η	: 24	(%)	

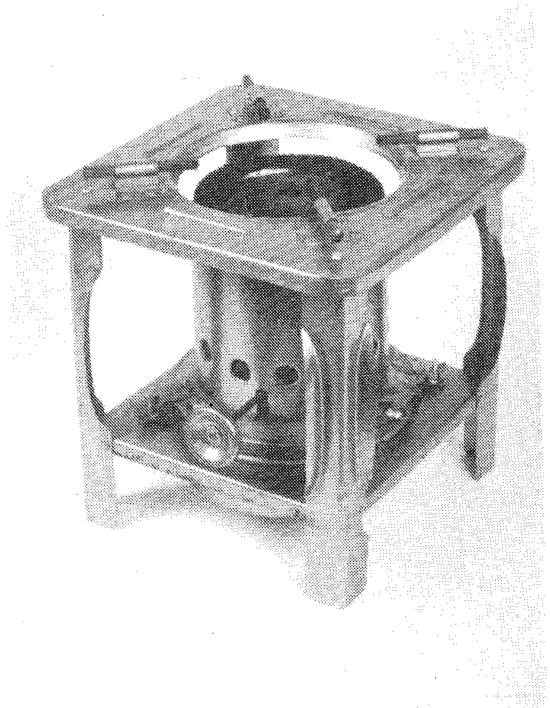
1) Flat wicks.
2) Shield and flame holder as one unit.
3) Whole bottom between shield and flame holder open.

Name	: Hock
Number	: 22
Manufact./country	: ?/Indonesia
Country of purchase	: Indonesia
Price	: 8 ($)
Weight (empty)	: 1,8 (kg)
Tank capacity	: 1,3 (kg)
Material/finish	: Aluminium, steel
Wick material	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

Overall dimensions (square)	: l × w × h	: 300 × 300 × 310	(mm)	
(round)	: d × h	:		
Number of wicks	: n_w	: 16		
Wick hole diameter	: d_w	: 8	(mm)	
Wick pitch circle	: d_p	: 100	(mm)	
Wick pipe length	: l_w	: 60	(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 85 × 90	(mm)	
(outside)	: $d_o \times h_a$	: 115 × 90	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,5	(mm)	
(outside)	: d_a	: 1,5	(mm)	
Flame holder holes pattern (inside)	: a × b	: 10 × 10	(mm)	
(outside)	: a × b	: 10 × 10	(mm)	
Central hole diameter	: d_c	: 10,4	(mm)	
Inside airholes (number)	: n_v	: 9		
(diameter)	: d_v	: 10	(mm)	1)
Outside airholes (number)	: n_u	: 28		
(diameter)	: d_u	: 10	(mm)	
Shields (number)	: n_s	: 1		
(diameter × height)	: $d_s \times h_s$	: 150 × 91	(mm)	
Shield top diameter	: d_t	: 135	(mm)	
Distance wick-panbottom	: h_w	: 135	(mm)	
Distance top flame holder-panbottom	: h_p	: 45	(mm)	
Minimum power	: P_{min}	: 0,4	(kW)	
Maximum power	: P_{max}	: 1,8	(kW)	
Nominal power	: P_{nom}	: 1,7	(kW)	
Efficiency with a pan of 18 cm diameter	: η	: 43	(%)	

1) Partition with holes 33 mm above holder bottom.

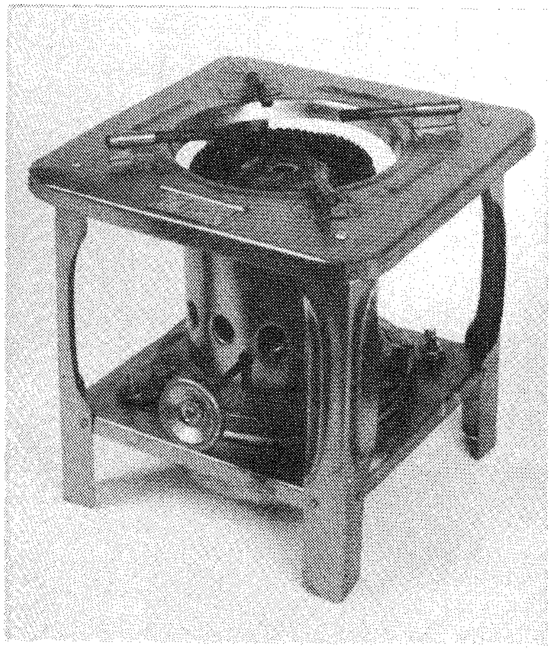
WICK STOVE DESCRIPTION



Name	: Swan 14
Number	: 6
Manufact./country	: ?/?
Country of purchase	: Indonesia
Price	: 5,50 ($)
Weight (empty)	: 2,4 (kg)
Tank capacity	: 0,8 (kg)
Material/finish	: Steel
Wick	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

Overall dimensions (square)	: l * w * h	: 275 * 275 * 295	(mm)	
(round)	: d * h	:		
Number of wicks	: n_w	: 14		
Wick hole diameter	: d_w	: 9	(mm)	
Wick pitch circle	: d_p	: 93	(mm)	
Wick pipe length	: l_w	: 52	(mm)	
Flame holder (inside)	: $d_i * h_a$	: 76 * 86	(mm)	
(outside)	: $d_o * h_a$	: 100 * 86	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,4	(mm)	
(outside)	: d_a	: 1,4	(mm)	
Flame holder holes pattern (inside)	: a * b	: 10 * 12	(mm)	
(outside)	: a * b	: 10 * 12	(mm)	
Central hole diameter	: d_c	: 14	(mm)	
Inside airholes (number)	: n_v	: 1		
(diameter)	: d_v	: 76	(mm)	
Outside airholes (number)	: n_u	: 11		
(diameter)	: d_u	: 18	(mm)	
Shields (number)	: n_s	: 1		
(diameter * height)	: $d_s * h_s$	: 140 * 120	(mm)	1)
Shield top diameter	: d_t	: 118	(mm)	
Distance wick-panbottom	: h_w	: 125	(mm)	
Distance top flame holder-panbottom	: h_p	: 39	(mm)	
Minimum power	: P_{min}	: 0,3	(kW)	
Maximum power	: P_{max}	: 1,3	(kW)	
Nominal power	: P_{nom}	: 1,2	(kW)	
Efficiency with a pan of 14 cm diameter	: η	: 39	(%)	

1) Shield also encloses the wick pipes.



Name	: Swan 20
Number	: 36
Manufact./country	: ?/?
Country of purchase	: Indonesia
Price	: 6,25 ($)
Weight (empty)	: 3,4 (kg)
Tank capacity	: 1,5 (kg)
Material/finish	: Steel
Wick material	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

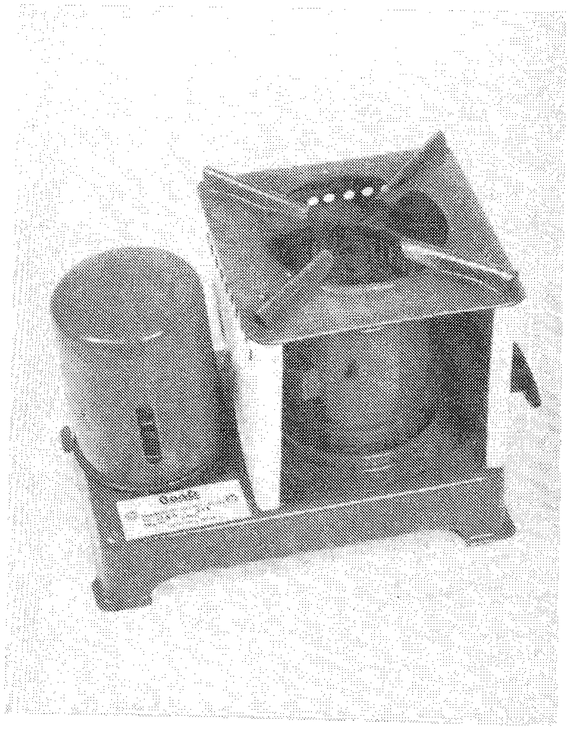
Overall dimensions (square)	: l × w × h	: 300 × 300 × 300	(mm)	
(round)	: d × h	:		
Number of wicks	: n_w	: 20		
Wick hole diameter	: d_w	: 9	(mm)	
Wick pitch circle	: d_p	: 120	(mm)	
Wick pipe length	: l_w	: 54	(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 103 × 107	(mm)	
(outside)	: $d_o \times h_a$	: 125 × 107	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,4	(mm)	
(outside)	: d_a	: 1,4	(mm)	
Flame holder holes pattern (inside)	: a × b	: 12 × 10	(mm)	
(outside)	: a × b	: 12 × 10	(mm)	
Central hole diameter	: d_c	: 17	(mm)	
Inside airholes (number)	: n_v	: 1		
(diameter)	: d_v	: 90	(mm)	
Outside airholes (number)	: n_u	: 12		
(diameter)	: d_u	: 18	(mm)	
Shields (number)	: n_s	: 1		1)
(diameter × height)	: $d_s \times h_s$	: 163 × 163	(mm)	
Shield top diameter	: d_t	: 150	(mm)	
Distance wick-panbottom	: h_w	: 154	(mm)	
Distance top flame holder-panbottom	: h_p	: 47	(mm)	
Minimum power	: P_{min}	: 0,5	(kW)	
Maximum power	: P_{max}	: 2,0	(kW)	
Nominal power	: P_{nom}	: 1,7	(kW)	
Efficiency with a pan of 18 cm diameter	: η	: 41	(%)	

1) Shield also encloses wick pipes.

Name	: Lark, T 733
Number	: 35
Manufact./country	: Lark Co./Peoples Rep. of Ch
Country of purchase	: Jemen
Price	: 9 ($)
Weight (empty)	: 1,9 (kg)
Tank capacity	: 0,9 (kg)
Material/finish	: Steel/enamel
Wick material	: Cotton
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.1

Overall dimensions (square)	: l × w × h:			
(round)	: d × h	: 226 × 238	(mm)	
Number of wicks	: n_w	: 10		
Wick hole diameter	: d_w	: 8,7	(mm)	
Wick pitch circle	: d_p	: 86	(mm)	
Wick pipe length	: l_w	: 33	(mm)	
Flame holder (inside)	: $d_i \times h_a$	: 73 × 100	(mm)	
(outside)	: $d_o \times h_a$	: 102 × 100	(mm)	1)
Flame holder holes diameter (inside)	: d_a	: 2,5	(mm)	
(outside)	: d_a	: 2	(mm)	
Flame holder holes pattern (inside)	: a × b	: 9 × 12	(mm)	
(outside)	: a × b	: 10 × 20	(mm)	
Central hole diameter	: d_c	: 6	(mm)	
Inside airholes (number)	: n_v	: 6 1		
(diameter)	: d_v	: 6 12	(mm)	
Outside airholes (number)	: n_u	: 3		2)
(diameter)	: d_u	: 14 × 116	(mm)	
Shields (number)	: n_s	: 1		
(diameter × height)	: $d_s \times h_s$	: 140 × 110	(mm)	
Shield top diameter	: d_t	: 96	(mm)	
Distance wick-panbottom	: h_w	: 140	(mm)	
Distance top flame holder-panbottom	: h_p	: 40	(mm)	
Minimum power	: P_{min}	: 0,5	(kW)	
Maximum power	: P_{max}	: 1,4	(kW)	
Nominal power	: P_{nom}	: 1,3	(kW)	
Efficiency with a pan of 16 cm diameter	: η	: 41	(%)	

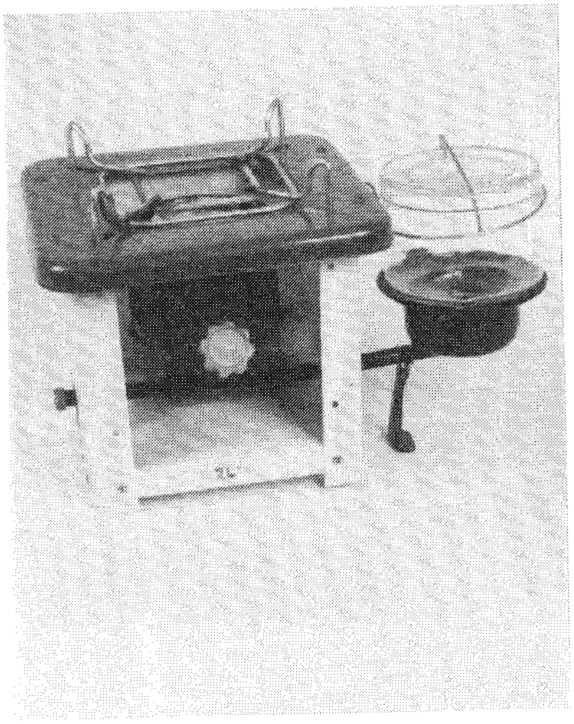
1) Top of outside wall flame holder curved inwards to diameter = 96 (mm).
2) Three slot-holes.



Name	: Prabhakar
Number	: 13
Manufact./country	: Ogale Ind. Ltd./India
Country of purchase	: India
Price	: 15,50 ($)
Weight (empty)	: 3 (kg)
Tank capacity	: 0,2 (kg) 1)
Material/finish	: Steel/enamel
Wick material	: Asbestos
Fuel level indication	: Yes 1)
Fuel	: Kerosene
Type	: See fig.: 4.2

Overall dimensions (square)	: l × w × h	: 273 × 180 × 205	(mm)	
(round)	: d × h	:		
Number of wicks	: n_w	: 1		2)
Wick hole diameter	: d_w	:		2)
Wick pitch circle	: d_p	: 70	(mm)	
Wick pipe length	: l_w	:		2)
Flame holder (inside)	: $d_i \times h_a$	: 60 × 100	(mm)	3)
(outside)	: $d_o \times h_a$	: 84 × 107	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,8	(mm)	
(outside)	: d_a	: 1,8	(mm)	
Flame holder holes pattern (inside)	: a × b	: 8 × 8	(mm)	
(outside)	: a × b	: 8 × 8	(mm)	
Central hole diameter	: d_c	: 12,5	(mm)	
Inside airholes (number)	: n_v	: 1 16		
(diameter)	: d_v	: 15 5	(mm)	
Outside airholes (number)	: n_u	: 16		
(diameter)	: d_u	: 7	(mm)	
Shields (number)	: n_s	: 1		
(diameter × height)	: $d_s \times h_s$	: 105 × 115	(mm)	3)
Shield top diameter	: d_t	: 85		
Distance wick-panbottom	: h_w	: 154	(mm)	
Distance top flame holder-panbottom	: h_p	: 45	(mm)	
Minimum power	: P_{min}	: 0,3	(kW)	4)
Maximum power	: P_{max}	: 2,0	(kW)	
Nominal power	: P_{nom}	: 1,7	(kW)	
Efficiency with a pan of 20 cm diameter	: η	: 42	(%)	

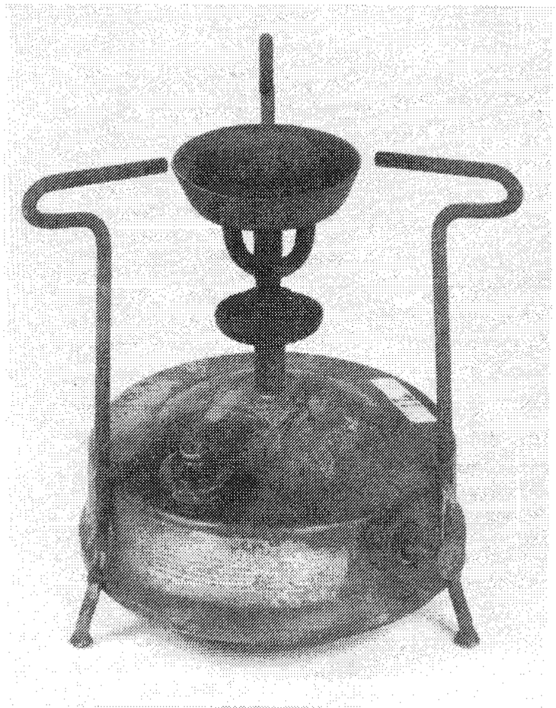
1) Fuel in a separate glass container.
2) One circular wick, thickness 3 mm. Wick space 5 mm.
3) Shield and flame holder as one unit.
4) Control by a valve to regulate the flow of kerosene to the wick.



Name	: Axe
Number	: 24
Manufact./country	: Lee Tai Metal Works/Mala
Country of purchase	: Singapore
Price	: 24 ($)
Weight	: 3,5 (kg)
Tank capacity	: 1,1 (kg) 1)
Material/finish	: Steel/enamel
Wick material	: Asbestos
Fuel level indication	: Yes 1)
Fuel	: Kerosene
Type	: See fig.: 4.2

Overall dimensions (square)	: l × w × h	: 500 × 310 × 310	(mm)	
(round)	: d × h	:		
Number of wicks	: n_w	: 1		2)
Wick hole diameter	: d_w	:		2)
Wick pitch circle	: d_p	: 83	(mm)	
Wick pipe length	: l_w	:		2)
Flame holder (inside)	: $d_i \times h_a$	: 74 × 105	(mm)	
(outside)	: $d_o \times h_a$	: 97 × 120	(mm)	
Flame holder holes diameter (inside)	: d_a	: 1,4	(mm)	
(outside)	: d_a	: 1,4	(mm)	
Flame holder holes pattern (inside)	: a × b	: 10 × 8	(mm)	
(outside)	: a × b	: 10 × 8	(mm)	
Central hole diameter	: d_c	: 8	(mm)	
Inside airholes (number)	: n_v	: 1 76		
(diameter)	: d_v	: 7,5 2,7	(mm)	3)
Outside airholes (number)	: n_u	:		
(diameter)	: d_u	:		4)
Shields (number)	: n_s	: 1		
(diameter × height)	: $d_s \times h_s$	: 150 × 110	(mm)	
Shield top diameter	: d_t	: 103	(mm)	
Distance wick-panbottom	: h_w	: 140	(mm)	
Distance top flame holder-panbottom	: h_p	: 20	(mm)	
Minimum power	: P_{min}	: 0,4	(kW)	5)
Maximum power	: P_{max}	: 1,8	(kW)	
Nominal power	: P_{nom}	: 1,8	(kW)	
Efficiency with a pan of 16 cm diameter	: η	: 40	(%)	

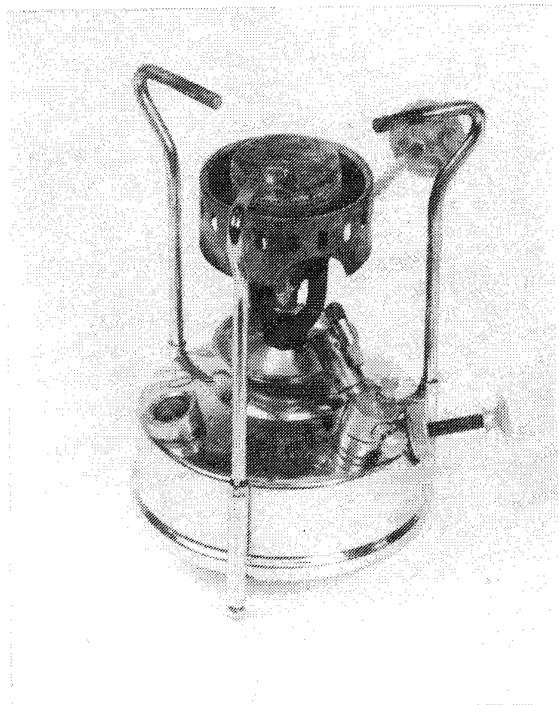
1) Fuel in separate glass container.
2) One circular wick, thickness 3 mm. Wick space 5 mm.
3) Second partition in inner flame holder wall at 27 mm from the bottom, with 37 holes of diameter = 5 mm.
4) Whole ring between flame holder wall and shield open.
5) Control by a valve to regulate the flow of kerosene to the wick.



Name	: Primus 505
Number	: 14
Manufact./country	: AB Optimus/Sweden
Country of purchase	: Netherlands
Price	: 45 ($)
Weight (empty)	: 1 (kg)
Tank capacity	: 0,7 (kg)
Material/finish	: Brass, steel
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.3

Overall dimensions	: d × h	: 190 × 214	(mm)	
Burner diameter	: d_b	: 47	(mm)	
Burner holes (number)	: n_h	: 195		
(diameter)	: d_h	: 1,5	(mm)	1)
Distance burner-panbottom	: h_p	: 8	(mm)	
Minimum power	: P_{min}	: 0,8	(kW)	
Maximum power	: P_{max}	: 2,4	(kW)	
Nominal power	: P_{nom}	: 2,4	(kW)	
Efficiency with a pan of 20 cm diameter	: η	: 54	(%)	

1) A so-called silent burner with three rows of little holes.



Name	: Annby 105
Number	: 15
Manufact./country	: Dea Rim/Korea
Country of purchase	: Netherlands
Price	: 60 ($)
Weight (empty)	: 0,9 (kg)
Tank capacity	: 0,4 (kg)
Material/finish	: Brass, steel/chromed
Fuel level indication	: Yes
Fuel	: Kerosene, petrol, diesel
Type	: See fig.: 4.3

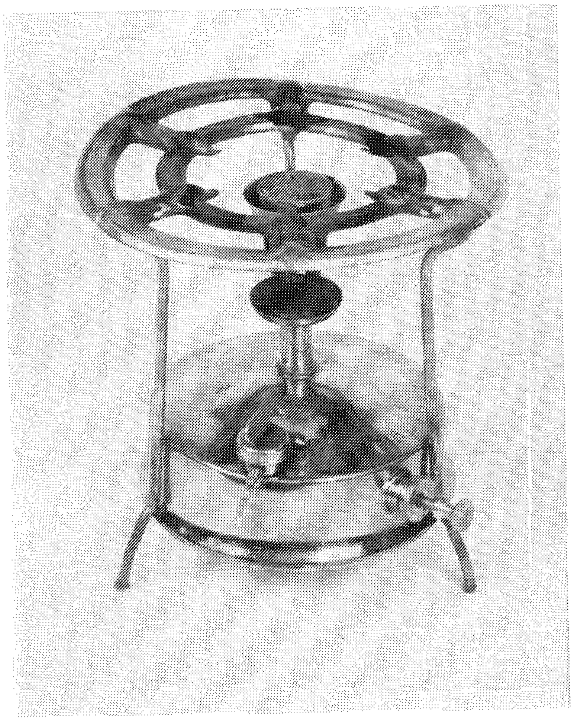
Overall dimensions	: d × h	: 140 × 187	(mm)	
Burner diameter	: d_b	: 44	(mm)	1)
Burner holes (number)	: n_h	: 360		
(diameter)	: d_h	: 1	(mm)	2) 3)
Distance burner-panbottom	: h_p	: 12	(mm)	
Minimum power	: P_{min}	: 0,4	(kW)	
Maximum power	: P_{max}	: 3,6	(kW)	
Nominal power	: P_{nom}	: 2,2	(kW)	
Efficiency with a pan of 24 cm diameter	: η	: 57	(%)	

1) Additional little shield around burner.
2) So-called silent burner with four rows of little holes.
3) Nozzle diameter not known.

Name	: Primus
Number	: 19
Manufact./country	: AB Optimus/Sweden
Country of purchase	: Netherlands
Price	: 45 ($)
Weight (empty)	: 0,9 (kg)
Tank capacity	: 0,6 (kg)
Material/finish	: Steel/painted
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.3

Overall dimensions	: d × h	: 190 × 197	(mm)	
Burner diameter	: d_b	: 54	(mm)	
Burner holes (number)	: n_h	:		
(diameter)	: d_h	:		1) 2)
Distance burner-panbottom	: h_p	: 7	(mm)	
Minimum power	: P_{min}	: 0,5	(kW)	
Maximum power	: P_{max}	: 1,5	(kW)	
Nominal power	: P_{nom}	: 0,9	(kW)	
Efficiency with a pan of 16 cm diameter	: η	: 49	(%)	

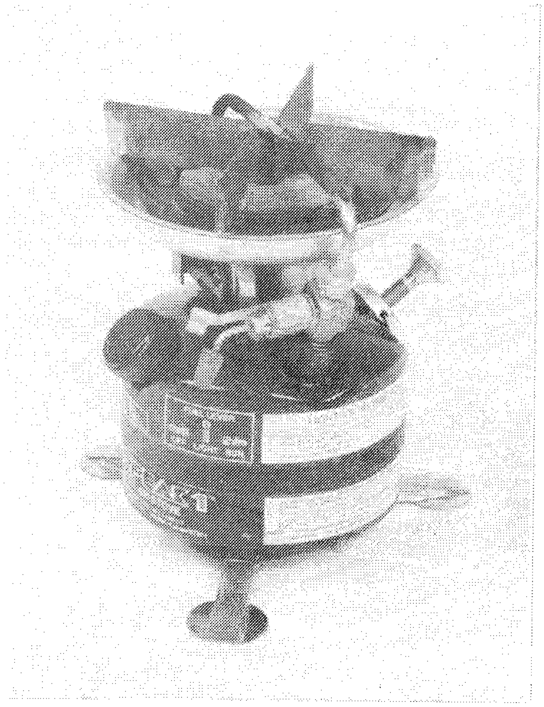
1) Open burner with four flames.
2) Nozzle diameter not known.



Name	: Russian Primus
Number	: 38
Manufact./country	: ?/USSR
Country of purchase	: Jemen
Price	: 9 ($)
Weight (empty)	: 1,3 (kg)
Tank capacity	: 0,7 (kg)
Material/finish	: Brass, steel
Fuel level indication	: No
Fuel	: Kerosene
Type	: See fig.: 4.3.

Overall dimensions	: d × h	: 220 × 216	(mm)	
Burner diameter	: d_b	: 52	(mm)	
Burner holes (number)	: n_h	:		1)
(diameter)	: d_h	:		2)
Distance burner-panbottom	: h_p	: 18	(mm)	
Minimum power	: P_{min}	: 0,5	(kW)	
Maximum power	: P_{max}	: 2,1	(kW)	
Nominal power	: P_{nom}	: 1,6	(kW)	
Efficiency with a pan of 20 cm diameter	: η	: 50	(%)	

1) Nozzle diameter not known.
2) Open, four flame, burner.



Name	: Peak 1, model 400
Number	: 16
Manufact./country	: The Coleman Co. Inc./USA
Country of purchase	: Netherlands
Price	: 50 ($)
Weight (empty)	: 0,9 (kg)
Tank capacity	: 0,3 (kg)
Material/finish	: Steel/painted
Fuel level indication	: No
Fuel	: Petrol
Type	: See fig.: 4.4

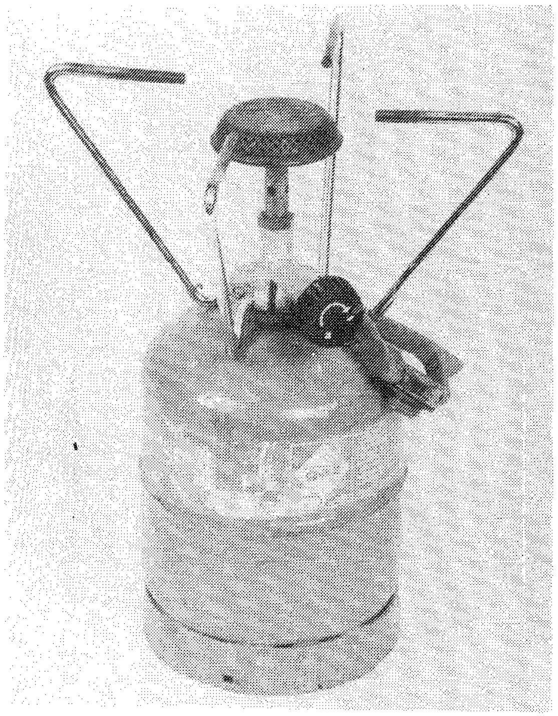
Overall dimensions	: d x h	: 160 x 155	(mm)	
Burner diameter	: d_b	: 60	(mm)	
Burner holes (number)	: n_h	:		
(diameter)	: d_h	:		1)
Distance burner-panbottom	: h_p	: 21	(mm)	
Minimum power	: P_{min}	: 0,4	(kW)	
Maximum power	: P_{max}	: 1,8	(kW)	
Nominal power	: P_{nom}	: 1,5	(kW)	
Efficiency with a pan of 18 cm diameter	: η	: 55	(%)	

1) Burner composed of waved steel plates.

Name	: Optimus 77A
Number	: 18
Manufact./country	: AB Optimus/Sweden
Country of purchase	: Netherlands
Price	: 25 (\$) 1)
Weight (empty)	: 0,71 (kg) 1)
Tank capacity	: 0,15 (kg)
Material/finish	: Aluminium, brass
Fuel level indication	: No
Fuel	: Spirit
Type	: See fig.: 4.5

Overall dimensions	: d * h	: 174 * 145	(mm)
Burner diameter	: d_b	: 39	(mm)
Air entrance holes (number)	: n_u	: 54	
(diameter)	: d_u	: 7	(mm)
Air supply holes (number)	: n_o	: 12	
(diameter)	: d_o	: 12	(mm)
Exhaust holes (number)	: n_t	: 54	
(diameter)	: d_t	: 7	(mm)
Distance burner-panbottom	: h_p	: 38	(mm)
Minimum power	: P_{min}	: 0,2	(kW)
Maximum power	: P_{max}	: 1,3	(kW)
Efficiency with a pan of 26 cm diameter	: η	: 61	(%)

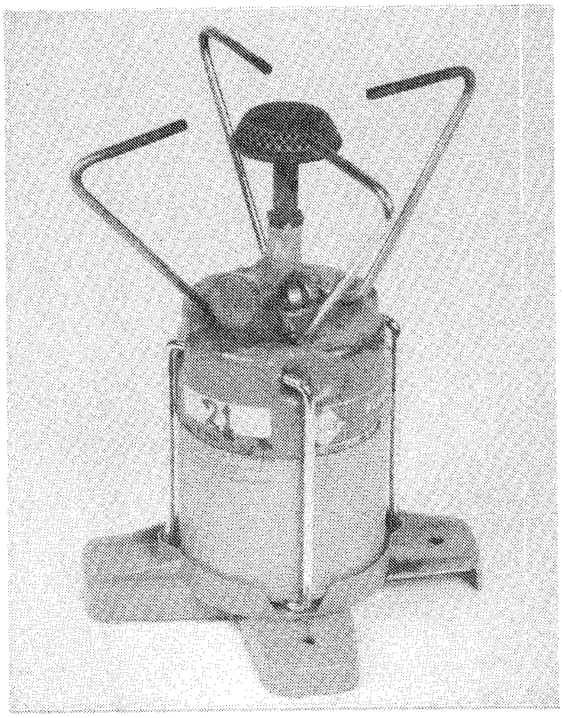
1) Complete set, including pans.



Name	: Camping Gaz Feu R
Number	: 20
Manufact./country	: Camping Gaz Int./France
Country of purchase	: Netherlands
Price	: 24 ($)
Weight (empty)	: 1,2 (kg)
Tank capacity	: 0,5 (kg)
Material/finish	: Steel/painted, chromed
Fuel level indication	: No
Fuel	: Butane
Type	: See fig.: 4.6

Overall dimensions	: d × h:	195 × 242	(mm)	
Burner diameter	: d_b	: 50	(mm)	
Burner holes (number)	: n_h	: 120		
(diameter)	: d_h	: 1,5	(mm)	1)
Distance burner-panbottom	: h_p	: 9	(mm)	
Minimum power	: P_{min}	: 0,4	(kW)	
Maximum power	: P_{max}	: 1,4	(kW)	
Nominal power	: P_{nom}	: 1,3	(kW)	
Efficiency with a pan of 16 cm diameter	: η	: 58	(%)	

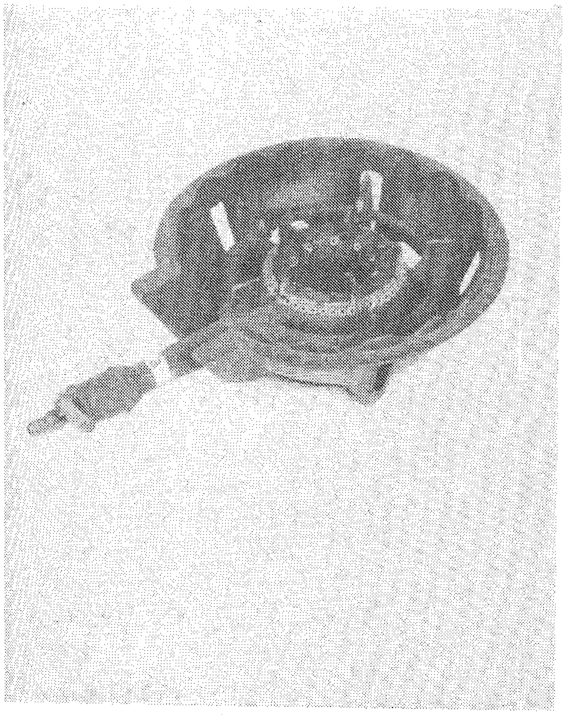
1) Nozzle diameter not known.



Name	: Camping Gaz Bluet
Number	: 21
Manufact./country	: Camping Gaz Int./France
Country of purchase	: Netherlands
Price	: 10 ($)
Weight (empty)	: 0,3 (kg)
Tank capacity	: 0,2 (kg) 1)
Material/finish	: Steel/painted, chromed
Fuel level indication	: No
Fuel	: Butane
Type	: See fig.: 4.6

Overall dimensions	: d × h:	175 × 220	(mm)	
Burner diameter	: d_b	: 40	(mm)	
Burner holes (number)	: n_h	: 90		
(diameter)	: d_h	: 1,5	(mm)	2)
Distance burner-panbottom	: h_p	: 8	(mm)	
Minimum power	: P_{min}	: 0,3	(kW)	
Maximum power	: P_{max}	: 1,2	(kW)	
Nominal power	: P_{nom}	: 1,1	(kW)	
Efficiency with a pan of 14 cm diameter	: η	: 58	(%)	

1) Refilling with one way cartouches
2) Nozzle diameter unknown.



Name	: Propane burner
Number	: 39
Manufact./country	: ?/Japan
Country of purchase	: Thailand
Price	: ?
Weight	: 5 (kg)
Tank capacity	: 1)
Material/finish	: Cast iron/painted
Fuel level indication	: 1)
Fuel	: Propane gas
Type	: See fig. 4.7

Overall dimensions	: d	: 277	(mm)	
	l_g	: 274	(mm)	
Burner diameter	: d_b	: 88	(mm)	
Burner holes (number)	: n_h	: 55		2)
(diameter)	: d_h	: 2,5	(mm)	
Distance burner-panbottom	: h_p	: 23	(mm)	
Minimum power	: P_{min}	: 3,5	(kW)	
Maximum power	: P_{max}	: 0,4	(kW)	
Nominal power	: P_{nom}	: 3,3	(kW)	
Efficiency with a pan of 24 cm diameter	: η	: 55	(%)	

1) Gas supply from tap or bottle.
2) 45 holes on the outside of the burner and 10 on the inside.

5. THE TEST PROCEDURE

Basically, two classes of tests were run on the selected stoves. The first set consisted of determining the maximum and minimum power (or in other words maximum and minimum rates of fuel consumption) permitted by the stoves. The second set consisted of determining the efficiency of the stoves by water boiling tests.

The instruments required for performing these tests were a set of balances to weigh the fuel and water, a stop-watch and a thermometer to measure the temperature of water. The balances used were:

(a) Molenschot & Zoon, Type AM 13623
Maximum weight 10 kg
Least count 1 g

(b) Mettler, Type K5
Maximum weight 2 kg
Least count 1 g

The stop-watch is an ordinary one (Hanhart Amigos) capable of measuring down to 1/5 of a second. A mercury-in-glass thermometer with a range of 0 - 110° C and a least count of 1° C was used for measuring temperatures.

The main concern in the testing procedure was to obtain reasonably accurate and reliable measurements. The main measurement is that of fuel weight. This requires some care. To illustrate this, a 2 kW stove uses a little over 160 g of kerosene in an hour. In order to assure a 1% accuracy it is necessary to conduct the test for a period of about 45 minutes. At lower power levels, one has to be satisfied with lesser accuracy since test durations become unduly long. Appendix 4 provides error estimates for the results obtained in this experimental programme.

The actual test procedure for determining the power levels used was as follows. The stove was lit and allowed to warm up. The warming-up period was of the order of 10 to 15 minutes. When the flames appeared steady to an observer, the test was started by noting the weight of the stove and starting the stop-watch. For the power level tests no pans were placed on the stoves. The tests were run for a period of about ½ hour with the weight of the stove and corresponding time recorded frequently. These tests were run simultaneously on 5 to 10 stoves at a time. Thus the weights and times were recorded by rotation. The power is inferred from the tests by

$$P = \frac{\Delta m_f . B}{\Delta t}$$

where P = power in kW
Δm_f = fuel consumed in kg during
Δt = the time interval in s
and B = lower calorific value in kJ/kg.

Before starting on the efficiency tests, it is necessary to select the pan size to be used with a given stove, since significant efficiency variations can be obtained by varying the pan size. In order to avoid bias in the results, pan sizes for all stoves were selected on the basis of a simple formula used by the V.E.G. Gas Institute in The Netherlands. Their recommended power density for gas stoves (defined as the ratio of maximum power and surface area of the pan bottom) is 7 W/cm^2. Higher power densities will reduce the life expectancy of the commercially available standard aluminium pans in Europe. This formula is illustrated in fig. 5.1 as a graph of pan diameter against the maximum power. In this graph also are shown the pan sizes obtained for the different stoves tested. Since pan diameters available commercially vary only in steps of 2 cm, the nearest diameter to the one found from fig. 5.1 was used in the tests. These are also indicated in the diagram.

There were indications that users of kerosene stoves tend to use pans with larger diameters than the ones selected according to the V.E.G. standards mentioned above. E.g. the manual of Nutan specifically mentions an increase of the result when using a larger vessel. Therefore an additional set of tests was done to measure efficiencies with a pan of 26 cm diameter.

Standard aluminium cylindrical pans with flat bottoms were used in the tests. The complete specifications of the pans used in the test programme are summarized in table 5.1.

Table 5.1. Specifications of pans used in the test programme

Sl. no.	Pan geometry		Pan weight kg	Volume of water l
	Diameter cm	Height cm		
1	14	7,5	0,25	0,74
2	16	8,5	0,25	1,02
3	18	10,1	0,32	1,60
4	20	11,0	0,44	2,05
5	24	12,6	0,62	3,53
6	26	15,3	1,05	4,57

The next question concerns the quantity of water to be used for the tests. The V.E.G. Gas Institute also recommends the heights to which the pans are to be filled for testing (see De Lepeleire et al., 1981,

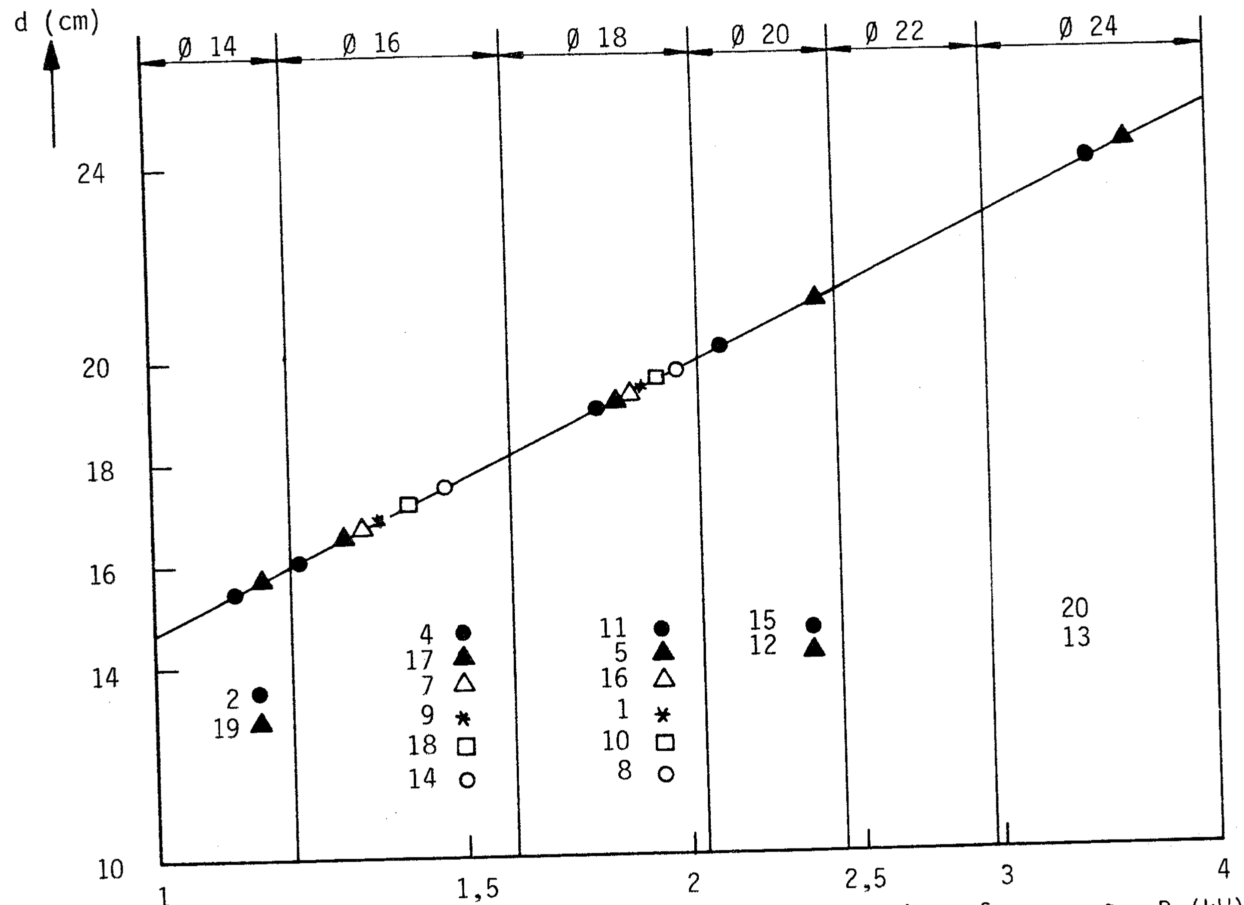


Fig. 5.1.Pan diameter as a function of power.

for V.E.G. recommendations). Since it was not possible to determine any rationale for this recommendation, we chose to adopt the recommendation given in the Provisional International Standards for testing woodstoves agreed to at a meeting in Arlington, Virginia (VITA, 1982). This latter states that 2/3 of the pan should be filled with water for water boiling tests. The actual quantity of water used for each pan in indicated in table 5.1.

The actual water boiling tests were carried out by lighting the stove (preferably at the chosen power setting) and waiting for the warm-up period. This was followed by weighing of the stove, placing the pre-weighed pan with water (whose initial temperature was measured beforehand) on the stove and starting the stop-watch. As soon as the water started boiling, the pan was removed and replaced by a second pan with an identical quantity of cold water on the stove. This procedure was carried out at least for an hour or till four pans were brought to boil. The weight of the pan at the end of each boiling period and the time were recorded. This procedure reduces the extent of errors introduced in the measurement. Appendix 3 provides a detailed discussion of the errors in the procedure adopted. At the end of the test, the weight of the stove is again recorded.

All the tests, unless otherwise stated, were performed on pans with their lids on. A few tests were conducted without the lid. Tests were also conducted with a single pan, but the water allowed to boil for 20 to 30 minutes depending on the amount of water that was used in the test. In these tests, the time at which the water started to boil, the weight of the pan, and the weight of the stove were also recorded for purposes of comparison.

The efficiencies for the tests conducted here were computed from

$$\eta = \frac{m_w(T_B - T_i)c_p + m_e H}{m_f B}$$

where η = efficiency
m_w = initial mass of water, kg
T_B = boiling temperature of water, 100° C
T_i = initial temperature of water, ° C
c_p = specific heat of water, 4,186 kJ/kgK
H = latent heat of evaporation of water, 2257 kJ/kg
m_e = mass of evaporated water, kg
m_f = fuel used in the test, kg
B = lower heating value of the fuel, kJ/kg.

The major characteristics of the fuels used in these tests, as provided by Eindhovense Olie Centrale (Eindhoven's Oil Centre), are summarized in Appendix 4.

Before starting with the tests, about two weeks were spent on familiarizing with the operation of the stoves and carrying out a few dry runs.

6. RESULTS AND DISCUSSION

In this chapter we present the results collected during the entire testing programme. The results are discussed with reference to a few design and operational characteristics. In addition some calculations on fuel use for cooking are included.

6.1. Power and efficiency test results

These values have already been presented in the data sheets in chapter 4. For the sake of convenience of the reader, these results have been assembled in table 6.1. In all 20 stoves, belonging to different categories as shown below, were tested.

Wick stoves	11
Pressurized stoves	5
Gas stoves	3
Floating pool stove	1

The tests on two wick stoves, with the brand names Surya (3-11) and Ideal (6-25) were discontinued, since the stoves arrived at Eindhoven incomplete. Trying to use the flame holders from other stoves did not prove very successful. The pumping handle of one pressure stove, from the USSR (15-38) broke down during the initial testing phase. The test, however, could be completed with an improvised arrangement.

The table records three power quantities: P_{max}, P_{min} and $\overline{P}$, corresponding to maximum, minimum and average power respectively. The last one refers to the water boiling tests. In principle P_{max} and P_{min} are controlled by the initial wick setting and the travel of the wick permitted by the control mechanism. The latter is clearly determined by the manufacturer. But the former is essentially at the user's discretion, particularly because the wicks have to be trimmed quite often and replaced periodically. The manufacturers' manuals for the Ashok and Nutan stoves (1-7 and 2-8 respectively, Indian) provide an indication that wicks need to be trimmed once in two weeks. But they do not suggest the frequency with which wicks need to be replaced. The Lark (9-35, Chinese) manual does not provide any information about the wick adjustment.

The situation described above has led to some discrepancies between the results of the present tests and the manufacturers' claims. The wick setting for the results shown in table 6.1 was done by holding the wicks in level with the top of the wick tubes. At this position of the wicks the control mechanism was held at its lowest setting. It was expected that for this setting, the flame power was at its lowest. To determine the maximum power, the control lever was raised until the blue flames turned yellow. For most of the stoves tested there was some more travel of the lever - of the order of 10 to 20% - possible beyond the setting described above. When the control setting is pushed

Table 6.1. Summary of results obtained in the test programme

Sl. no.	Brand name	Ident. no.	Power tests					Efficiency tests			Efficiency %	
			P_{max} kW	P_{min} kW	$\frac{P_{max}}{P_{min}}$	Pan dia. cm	$\overline{P}$ kW	Time for boiling m.	m./l	$\overline{\sigma}$, %		
1	Ashok	7	2,0	0,6	3,1	18	1,9	9,9	6,2	2,0	48	
2	Nutan	8	1,1	0,2	5,0	14	1,2	8,5	11,5	6,8	44	
3*	Surya	11	1,0	0,1	7,6	--	--	--	--	--	--	
4	Divyajyoti	12	1,2	0,1	3,1	16	1,2	15,1	14,8	20,1	24	
5	Hock	22	1,8	0,4	5,1	18	1,7	12,6	7,9	1,6	43	
6*	Ideal	25	--	--	--	--	--	--	--	--	--	
7	Swan 14	6	1,3	0,3	4,3	14	1,2	9,8	13,2	3,7	39	
8	Swan 20	36	2,0	0,5	4,2	18	1,7	13,7	8,6	2,4	41	Wicks
9	Lark	35	1,4	0,3	4,0	16	1,3	11,6	11,4	1,9	41	
10	Prabhakar	13	2,0	0,3	7,5	20	1,7	16,7	8,1	3,6	41	
11	Axe	24	1,8	0,4	4,3	16	1,8	9,0	8,8	5,6	39	
12	Primus 505	14	2,4	0,8	2,9	20	2,4	8,7	4,2	11,5	54	
13	Annby	15	3,6	0,4	9,0	24	2,2	16,2	4,6	3,5	56	
14	Primus	19	1,5	0,5	3,3	16	0,9	13,6	13,3	20,6	49	Pressurized
15	Primus (USSR)	38	2,1	0,5	4,4	20	1,6	14,8	7,2	1,0	50	
16	Peak 1	16	1,8	0,4	4,4	18	1,5	11,0	6,9	3,5	55	
17	Optimus 77A	18	1,3	0,2	8,0	16	1,3	7,0	6,9	6,9	61	Spirit
18	Camping Gaz Feu R	20	1,4	0,4	3,3	16	1,3	7,7	7,6	5,8	58	
19	Camping Gaz Bluet	21	1,2	0,3	4,6	14	1,1	7,0	9,5	7,8	58	Butane
20	Propane Burner	39	3,5	0,4	8,2	24	3,3	11,3	3,2	3,8	55	

Notes: * Tests discontinued (see text).
$\overline{\sigma}$ Standard deviation defined by $\overline{\sigma} = \frac{1}{\overline{x}}\left[\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2\right] \times 100\%$

where $\overline{x} = \frac{1}{n}\sum_{1=1}^{n} x_i$

to its limit, the fuel burns with yellow flames and a considerable part of the flames is outside the flame holder. We felt this to be undesirable from two points of view - sooting of pans and increased fuel consumption. Thus all the P_{max} quoted in table 6.1 correspond to what can be called "blue flame limited maximum power".

For the minimum power, the control lever was lowered to the minimum position. At this position most of the stoves burned with a yellow flame at the wick tips. This was considered undesirable from the point of view of wick life-time and too low a power output for any useful cooking operation. The lever was raised to such an extent that blue flames just appeared in the flame holder. This can be called the "blue flame limited minimum power".

The maximum power obtained by this procedure differed considerably from the manufacturer's specification of fuel consumption rates, for Lark and Nutan. A detailed review of the work done here was undertaken and the procedures were carefully reviewed with respect to manufacturer's recommendations. At this time it was realized the wick setting in these studies differed from the one recommended by the manufacturer of Nutan. According to this recommendation, the wicks at the lowest position of the control lever should be in level with the outer rim of the wick carrier. This is about 6 to 8 mm higher than the level adopted in the tests. It was decided at this stage to rerun the power level experiments on Nutan and Lark using the recommendations of the manufacturer of Nutan. Further another stove, Ashok*, was added to the list of stoves tested as its leaflet also specified fuel consumption rate. The results of this work are tabulated in table 6.2.

The revised wick setting did indeed increase the P_{max} quite dramatically in the cases of Nutan and Lark, but only modestly that of Ashok. More importantly, there was a sharp drop in the ratio of P_{max}/P_{min} with the wick setting revised according to the manufacturer's recommendations. As will be shown later in this chapter, this ratio is of decided importance in determining the fuel economy of a stove particularly for cooking situations with substantial period of simmering operations. Higher the ratio P_{max}/P_{min}, greater is the fuel economy. In this respect Nutan, which was the best from this point of view according to the wick setting procedure adopted in the tests here, turned out to be the

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* This stove was not included in the original list due to three reasons: it was very similar to Nutan; it was from India; Nutan was preferred since it had received considerable publicity in India and had been mentioned in an Indian Energy Study (Desai, '79).

worst when the manufacturer's procedure was adopted. However, it is also to be seen that the revised tests showed much higher P_{max} than the ones specified by the manufacturers for all the stoves tested.

Table 6.2. Power test comparisons of 3 stoves (in kW)

Stove	I	II		III	
	P_{max}	P_{max}	P_{min}	P_{max}	P_{min}
Ashok	1,81*	1,95	0,64	2,20	1,95
Lark	1,81	1,35	0,34	2,80	1,81
Nutan	1,57	1,11	0,22	1,88	1,75

Notes: I Manufacturer's specifications
II Tests of the type in table 6.1
III Revised tests

* Average power corresponding to fuel consumption rates of 140 - 160 g/h.

Another unsuspected problem was encountered during the power tests. The power level of the fire rarely remained steady. Figure 6.1 is a plot of variation in P_{max} with time for six stoves. Three principal features emerge from a study of this plot. Firstly, all stoves seem to record a drop in power with time. Secondly, this drop is substantial - of the order of a third or more - for the pressurized stoves. Finally, there is considerable noise in the data. Among the results depicted in the figure, Lark is the only one which holds its power reasonably steady. It has not been possible to analyze the reasons for this behaviour during the course of this investigation. Our guess is that the drop in power of pressurized stoves is drop in pressure during the course of the test with corresponding decrease in fuel supply rate to the burning zone. It is surmized that the ability of the wick (in the case of wick stoves) to maintain a given fuel supply rate to the burning zone also reduces with time. Thus the P_{max} values in table 6.1 correspond to average fuel consumption rate over the whole test period. Barring 5 stoves, all the others have a power rating less than 2 kW. Nutan has the smallest power of all the tested stoves.

The results of P_{min} show similar behaviour and the values shown in table 6.1 have been computed by the same method used for P_{max}. As pointed out earlier, the turn-down ratios (P_{max}/P_{min}) are of importance in determining the fuel economy of a stove used for cooking. These are also shown in the table. In general ratios

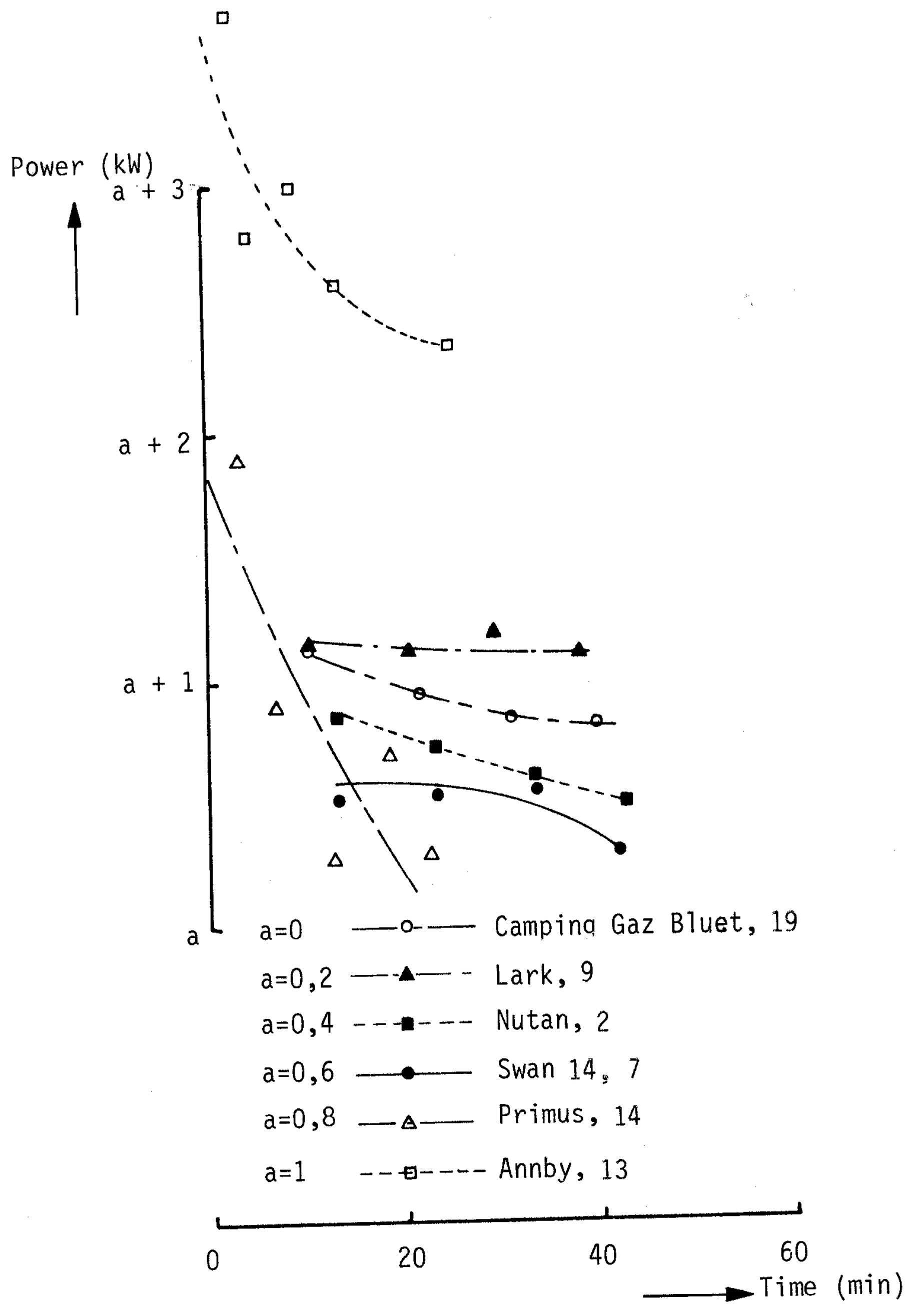

Fig. 6.1. Power variation as a function of time.

much below 4 should be considered poor from this point of view. Five of the stoves tested belong to this category. We use this ratio as a means to rate the stoves in a later section of this chapter.

We now turn our attention to the efficiency test results, which are also included in table 6.1. These tests were all conducted at the maximum power setting of the stove. Thus the $\overline{P}$ data should agree with the P_{max} data presented earlier. The striking result that emerges from this comparison is that all the pressure stoves (with the sole exception of Primus 505) show exceptionally large differences between the two sets of data. The reason for these differences must be attributed to the fact that power tests were conducted for a short period - of the order of 20/30 minutes while the efficiency tests were run for a period of one hour or so. It can be seen from the behaviour of these stoves in fig. 6.1 that the power curve flattens out after a certain period. Thus the average $\overline{P}$ is weighted in favour of the low power operation resulting in the discrepancies. The standardization of this procedure requires much more time than was available for this investigation and as such we have decided to live with these discrepancies.

In order to make sure that the power tests, that were carried out earlier, did not have any serious error in them, they were repeated on two stoves - the Primus 505 (12-14) and the Swan 14 (7-6) - for a period of one hour. Fuel weight loss for both the stoves was recorded at regular intervals and power was calculated as before. These results are compared with those of table 6.1 in table 6.3. For this class of work this level of repeatability should be considered adequate.

Table 6.3. Confirmation test results

	Primus 505 (12-14)	Swan 14 (7-6)
$P^{(1)}_{max}$, kW (from table 6.1)	2,38	1,32
$P^{(2)}_{max}$, kW (confirmation test)	2,24	1,22
$\overline{\sigma}$ % (confirmation test)	4	7
$\dfrac{P^{(1)}_{max} - P^{(2)}_{max}}{P^{(1)}_{max}}$, %	5,8	7,6

The wick stoves on the average show much smaller deviations between P_{max} and $\bar{P}$. The exceptions are the Swan stoves and the Prabhakar. Even these show substantially smaller deviations than the pressurized stoves. Thus it seems fair to conclude that for operational periods of the order of 1 hour or so, there is no need to adjust the wicks for maintaining reasonably constant power.

The second piece of information that emerges from this series of tests is the time required for bringing a given quantity of water to boil. Since the quantities of water used varied with the pans, we have also given the time in minutes per litre of water to be brought to boil. Further, since each test comprised of bringing four or more pans of water to boil, the times indicated in this table are averages. To detect any systematic variation in the results of times obtained for individual boilings, standard deviations* for each set were determined and are tabulated in table 6.1. An examination of these data indicates that only 3 stoves showed standard deviations in excess of 10%. We conclude from these that the measurement technique employed in this study is satisfactory.

We now turn to the all important question of the efficiency of the stoves. Strictly speaking the formula quoted in chapter 5 when applied to the present series of tests should be modified as follows.

$$\eta = \frac{\sum_{j=1}^{n} m_{w,j}(T_B - T_{i,j})c_p + m_{e,j}H}{m_f B}$$

Where n is the number of pans brought to boil. The symbols $m_{w,j}$, $T_{i,j}$ and $m_{e,j}$ explicitly account for the inevitable small changes that were too difficult to control for each of the pan fillings. The data obtained are listed in the last column of table 6.1.

The stoves tested in this programme fall into four categories, each category with a distinct efficiency number. The wick stoves (serial numbers 1 to 11) have an average efficiency of 40%; the pressurized stoves (serial numbers 12 to 16) 53%; the pool burner (serial number 17) 61%; and the gas stoves (serial numbers 18 to 20) 57%. A bias in these tests should be pointed out at this stage. The pan size for this programme of tests was chosen on the basis of power tests, where on the average the P_{max} was much higher for the pressure stoves than the P_{max} measured in the efficiency tests. We will discuss the extent of pan size influence on efficiency in the next section. From that discussion it emerges that our pan selection procedure unduly favours the pressure stoves. Another point to be noted is that among the wick stoves tested Divyajyoti (4-12) showed a very low efficiency of 24%. If we omit this from consideration, the average efficiency moves up to 43% for the wick stoves tested. Thus if we take the bias in pan selection into account in addition, the wick stoves show probably a 5 percentage point lower efficiency than the pressure stoves. See section 6.2 for the effect of pan diameter on efficiencies. Considering the fact that wick stoves are much easier to manufacture and cheaper than the pressure stoves, this disadvantage seems to be quite small.

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* Standard deviations tabulated in table 6.2 are also referred to in the literature as coefficient of variation.

There is little doubt that the gas stoves have a decided advantage over the wick stoves. The problem here is one of gas supply situation and the cost of the apparatus, both of which appear to be substantial in developing countries at the moment.

6.2. Efficiency as a function of other parameters

In our association with the woodstoves we have found two issues that have caused considerable concern among people working on the problem. These are the use of lids while testing and the continuation of the test through the boiling regime. We provide some quantitative evidence in this regard for a few stoves so that meaningful use of the information provided in the previous section could be made.

The effect of a lid was tested on two stoves - the Prabhakar with a 20 cm pan and the Annby with a 24 cm pan. The results obtained are summarized in table 6.4. The test procedure used was the same as the one used in the earlier case. The results do not show any preference for the use or nonuse of a lid at least from the point of view of efficiency. However, it is altogether a different issue when one considers fuel consumption. These are 23% and 27% more without lid for Prabhakar and Annby respectively. The fact that efficiencies do not show similar changes is attributed to the method of calculating efficiencies here. The justification for our approach lies in the interpretation of efficiency. We mean by efficiency the effectiveness with which the chemical energy stored in the fuel is converted into heat energy and the effectiveness with which the latter is transferred into the pan.

Table 6.4. Effect of lid on efficiency

Sl. no.	Stove	Quantities	With lid	Without lid
1	Prabhakar (10-13)	$\overline{P}$ (kW)	1,73	1,63
		Time for boiling (minutes)	16,7	21,8
		$\overline{\sigma}$ (%)	3,6	6,4
		η (%)	41,5	45,5
		Fuel consumption, g	40	49
2	Annby (13-15)	$\overline{P}$ (kW)	2,17	2,62
		Time for boiling (minutes)	16,25	17,1
		$\overline{\sigma}$ (%)	3,6	11,6
		η	56,6	54,6
		Fuel consumption, g	48	61

Table 6.5. Effect of prolonging the test into boiling regime

Sl. no.	Stove	Quantities	With boiling	Without boiling
1	Camping Gaz Bluet (19-21) Pan dia.: 14 cm	$\overline{P}$ (kW) t_b (minutes) η (%)	1,11 20 59,5	1,07 -- 58,2
2	Lark (9-35) pan dia.: 16 cm	$\overline{P}$ (kW) t_b (minutes) η (%)	1,11 25 38,1	1,25 -- 40,7
3	Swan 20 (8-36) Pan dia.: 20 cm	$\overline{P}$ (kW) t_b (minutes) η (%)	1,69 30 43,1	1,76 -- 40,2

t_b = duration of prolongation into the boiling regime.

Table 6.5 summarizes the results obtained when the tests were continued through the boiling regime. The boiling durations were essentially determined by the quantity of water available at the start of the test. Smaller the pan, smaller the quantity of water and hence shorter the duration over which the boiling state was held to prevent the water boiling away. The results in the table do not show any significant variation between the two types of tests to warrant any conclusion as to the superiority of one form of test over another.

In conclusion these two sets of tests lend confidence in the methodology of testing adopted in this test programme.

A third series of tests were run on two stoves - the Camping Gaz Feu R (18-20) and the Hock (5-22) - to determine the effect of the power level of the fire on the efficiency. These effects are shown plotted in fig. 6.2. The pan sizes used in these two sets of tests were according to the tests summarized in table 6.1. The Camping Gaz Feu R for all practical purposes could be considered to have a constant efficiency within the experimental accuracy attained in this test programme. The Hock shows a monotonic decrease in efficiency with decrease in power level of the fire. As the power decreases from 1,71 to 0,45 kW the efficiency drops from 43,3 to 35,7%.

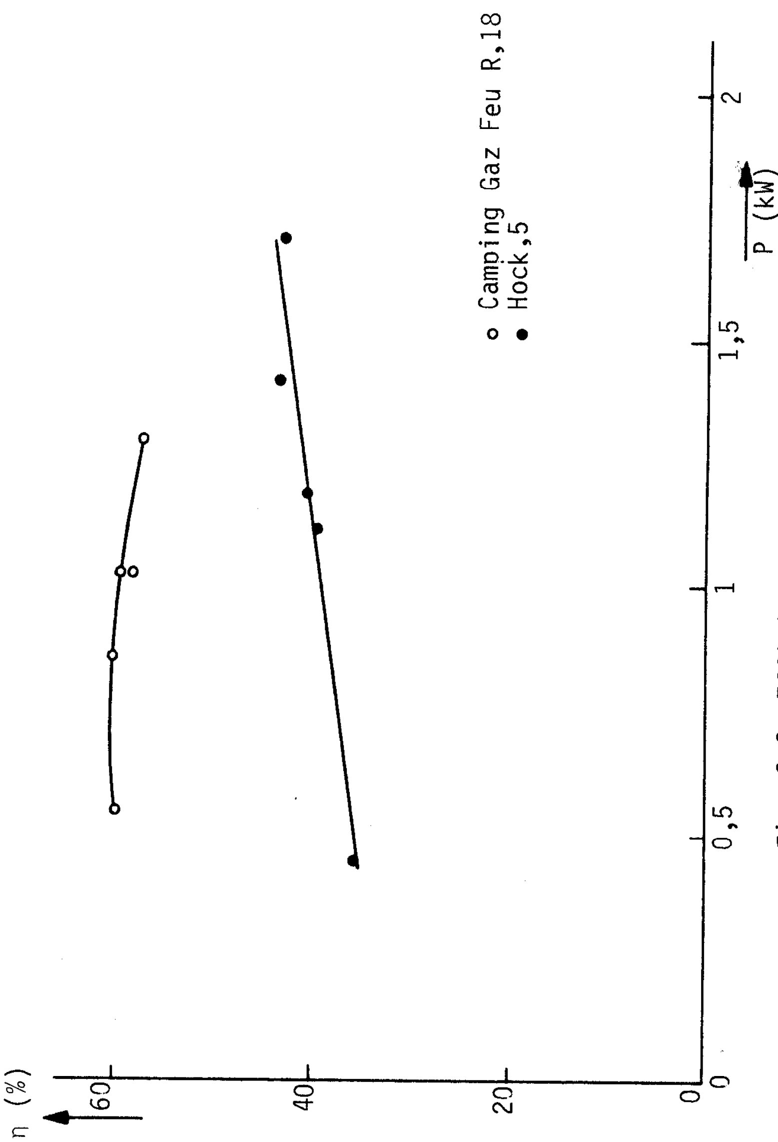

Fig. 6.2. Efficiency versus powerlevel of the stoves.

The final series of tests pertain to the influence of pan diameter on the efficiency. These tests were performed on three stoves: Swan 14 (7-6), Lark (9-35) and Primus (12-14). The efficiency and time for boiling are plotted against pan base area in fig. 6.3. All the three stoves record increases in efficiencies with increased pan base areas. The Lark is the one which shows a dramatic increase from a little over 40% to a little over 60%, when the pan base area increases from 200 cm^2 to 450 cm^2. There appears to be a maximum associated with the increase feasible; this seems to be clear at least in the case of Swan 14. The boiling times (in minutes/litre) seem to go through a minimum. This roughly corresponds to the maximum point in the efficiency curve. More definitive conclusions on these aspects are difficult to draw because of insufficient experiments.

In view of the fact that:
(a) the pan diameter has a significant effect on efficiency;
(b) the bias in selection of pan diameters for the tests reported in table 6.1; and
(c) the people in developing countries tend to use larger pan sizes than those used in the test reports in table 6.1;

additional tests with all the stoves were run at P_{max} with a single pan of 26 cm diameter. The results of these tests are shown in table 6.6. This table shows a marked increase in efficiency as expected. The wick stoves make the largest jump in efficiency of 9 percentage points to 51%, the pressure stoves increase with 7 percentage points to 60% efficiency, and the gas stoves barring the propane burner also increase with 7 percentage points from 58% to 65% on the average. The propane burner forms the only exception in the row with a drop of 12 percentage points to 43%, for the pan base was too big to fit the stove seat and as a result it obstructed the flow path of the hot gases.

As shown in the table Divyajyoti remains the stove with the lowest efficiency of 38%. The pressure stove Peak 1 and the gas burner Gaz Feu R both show the highest efficiency of 67%. It should be noted that for some inexplicable reason the Peak 1 performed with a much higher power output than in previous tests. Confirmation tests did not alter this situation. Of all stoves Nutan has the highest jump in efficiency from 44% to 63%.

Finally, efficiency test results that do not quote the pan types on which they were obtained should be treated with suspicion. This might be one of the reasons why it is so hard to compare results obtained by different people.

6.3. An analysis of designs

In this section we will attempt a somewhat general analysis of the designs that have been tested in this programme. Two kinds of analysis are presented. The first concerns the wick stove designs and the second attempts to look at the data collected in the study in more general terms. The intention is to get a better insight into the relationship between the designs and their performance.

Table 6.6. Comparison of results between tests with different pan sizes and tests with one pan size

Sl. no.	Brand name + (Ident. no.)	Different pan sizes			One pan size			
		Pan dia. cm	$\bar{P}$ kW	Efficiency %	$\bar{P}$ kW	Efficiency %	Time for boiling min.	Time for boiling min./l
1	Ashok (7)	18	1,9	48	1,8	56	25,1	5,5
2	Nutan (8)	14	1,2	44	1,2	63	34,0	7,4
3	Surya[1)] (11)	--	--	--	--	--	--	--
4	Divyajyoti (12)	16	1,2	24	1,2	38	60,2	13,2
5	Hock (22)	18	1,7	43	1,7	47	31,8	6,9
6	Ideal[1)] (25)	--	--	--	--	--	--	--
7	Swan 14 (6)	14	1,2	39	1,2	54	38,8	8,5
8	Swan 20 (36)	18	1,7	41	1,6	47	34,5	7,5
9	Lark (35)	16	1,3	41	1,5	58	30,8	6,7
10	Prabhakar (13)	20	1,7	41	2,0	49	26,6	5,8
11	Axe (24)	16	1,8	39	1,5	42	42,0	9,2
12	Primus 505 (14)	20	2,4	54	2,2	62	19,2	4,2
13	Annby[2)] (15)	24	2,2	56	--	--	--	--
14	Primus (19)	16	0,9	49	0,9	57	51,3	11,2
15	Primus (USSR) (38)	20	1,6	50	1,8	55	25,7	5,6
16	Peak 1 (16)	18	1,5	55	2,5	67	15,7	3,4
17	Optimus 77A[3)] (18)	16	1,3	61	--	--	--	--
18	Camping Gaz Feu R (20)	16	1,3	58	1,1	67	35,2	7,7
19	Camping Gaz Bluet (21)	14	1,1	58	0,8	62	49,5	10,8
20	Propane burner (39)	24	3,3	55	3,9	42	13,9	3,0

1) Test abandoned due to mal functioning of stove.
2) Test for big pan not carried out because the stove was not available anymore.
3) Test not done for big pan size because stove is especially adapted to one particular pan.

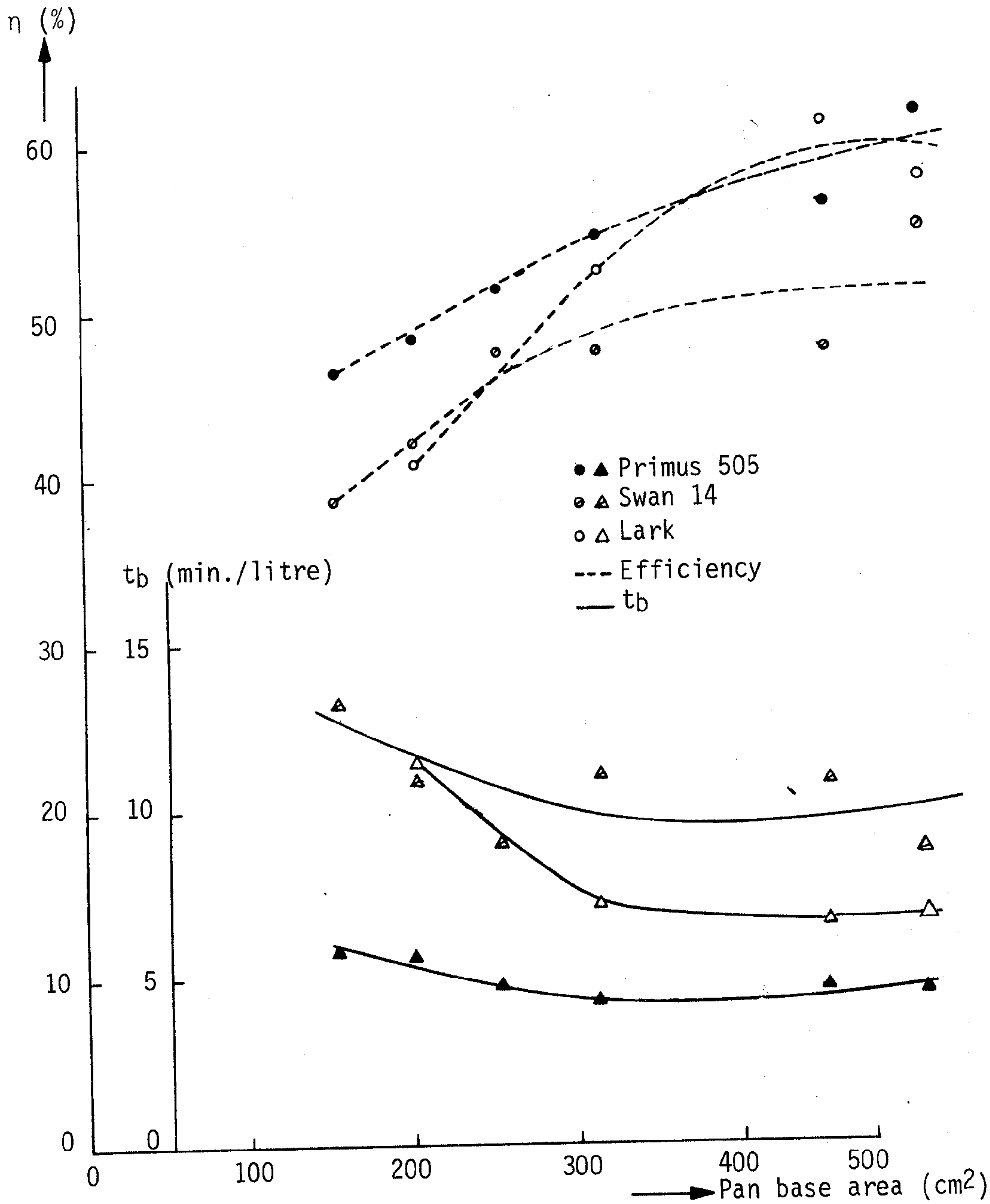

Fig. 6.3. Efficiency and time to boil as a function of pan base area.

At the outset the wick-top surface area was correlated with P_{max} and P_{min} obtained in the tests. These correlations are shown plotted in fig. 6.4. While there is considerable noise in the data, it is evident that both P_{max} and P_{min} increase with increase in the wick surface area. The straight lines drawn to represent these correlations show that P_{max}/P_{min} is about 5 for this class of stoves. This is the most important design information we could get from these correlations.

Attempts to correlate the area of the air-holes and the height of the flame holder with each other and with the wick surface area/power output proved futile. There was no attempt made to analyse the designs of pressure and gas stoves along the lines of what was done for the wick stoves.

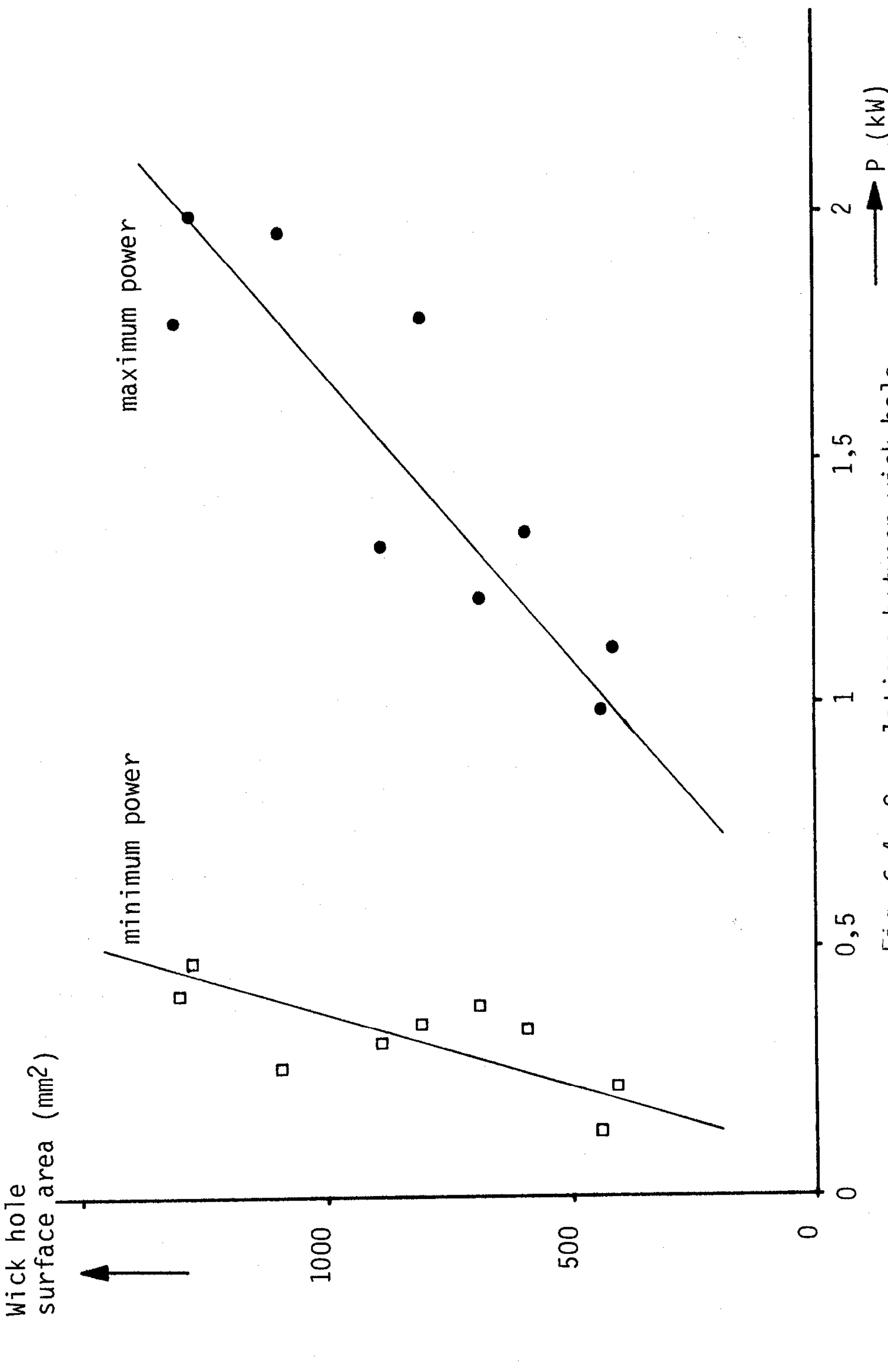

Fig. 6.4. Correlations between wick hole surface area and maximum and minimum power.

Next a generalization of the results of fig. 6.3 was attempted to provide an indication of the performance delivered by the stove-pan combination. Such a correlation was presumed to exist between efficiency and time for boiling a litre of water on the one hand and the power density (W/cm^2) on the other hand. All the results obtained in the present test programme are shown plotted in fig. 6.5. It is possible to draw average curves over the points for pressure and gas stoves. The efficiency curve is suspect since the noise in the data is roughly the same order as changes depicted by the curve. The curve representing the boiling times is more acceptable from the point of view of the noise in the data. The reason for this better correlation probably lies in the fact that many more boiling times were determined during the course of this work than the efficiency data. Moreover the efficiency seems to be a relatively weak function of the power density. It is interesting to note that the optimum value for the power density lies around 7 W/cm^2, the recommended value by VEG standards in the Netherlands.

The wick stoves, on the other hand, do not indicate any correlation on the basis of power density. More work is necessary to clarify this point further. One observation we can make is that most of the present results for wick stoves are below the average efficiency curve and above the average boiling time curve for pressure and gas stoves. However, we must repeat our proviso: the wick stoves can be made to perform better by choosing larger pan diameters than the ones used in this investigation. But then the question arises what happens with the efficiency at the low power output (P_{min})? Especially considering long simmering times it seems relevant to investigate this item closer.

6.4. Comparison of present results with earlier work

This seems an appropriate place to pause and take stock of the present results in the light of the results obtained earlier. A difficulty of comparing results from different investigations is with the availability of complete data. This is to a certain extent understandable since some of these studies covered much broader ground than stoves and hence time spent on stove testing was proportionately smaller. Thus to facilitate cross comparisons, we have not bothered with power levels, individual stoves and pan sizes. We have simply used averaged values across the board. We shall use the classification of stoves employed by Tschinkel & Tschinkel. Table 6.7 presents the results of such a comparison.

In general Islam's results both for the variable wick and gas burners tend to run higher since he used quite large pans. In spite of this, his results compare favourably with the results of Tschinkel & Tschinkel and the present work. The result of Tschinkel & Tschinkel is midway between Islam's and our results for the fixed wick burner. The low value in the case of Islam probably could be explained by the fact that he used only ½ kg of water and presumably much smaller pan sizes. The base area of the pan used for Prabhakar in the present case is larger than the one used by Tschinkel & Tschinkel. It is our belief that these results are compatible

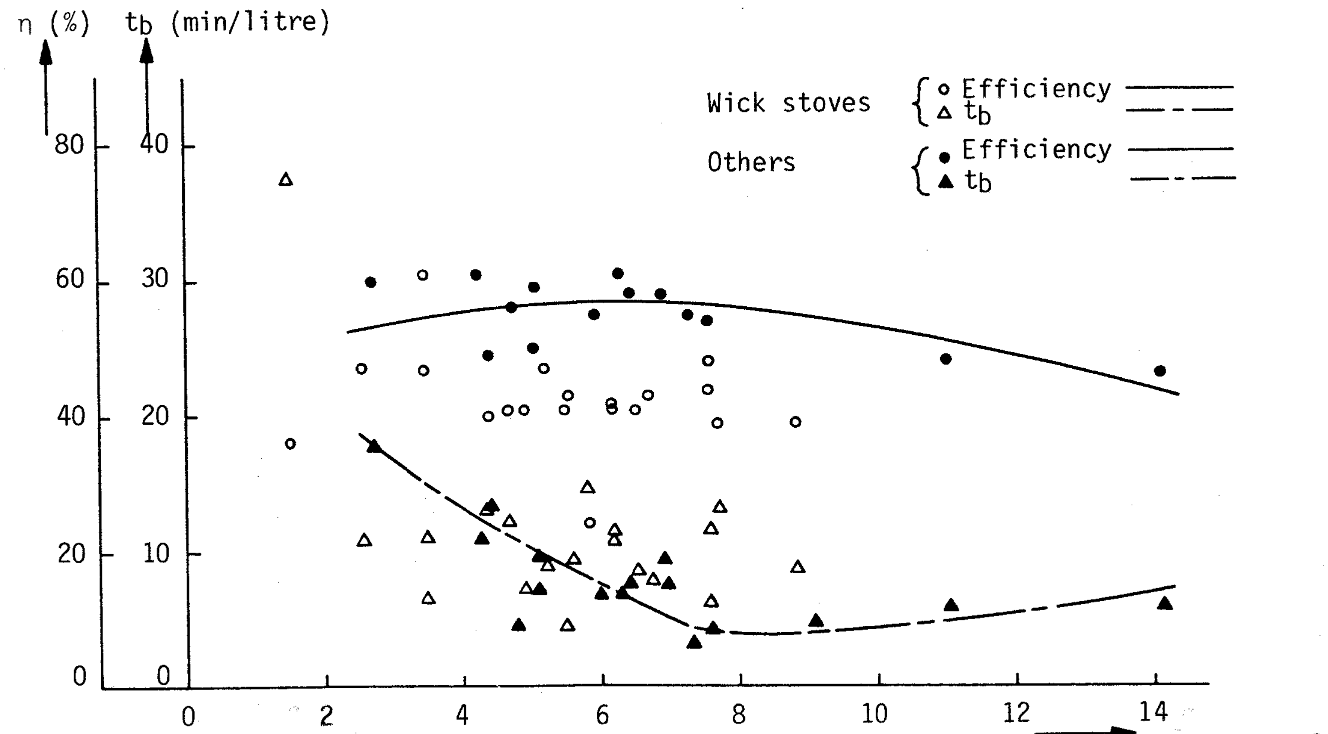

Fig. 6.5. Efficiency and boiling times as a function of power density.

with one another. The Fiji and NZCC results neither agree with each other nor with the other three. We find it hard to believe these results, particularly because the source material at our disposal was too sketchy to come to any definitive conclusions.

Table 6.7. Comparison of present results with earlier work

Sl. no.	Stove type	Parameters	Fiji 1)	NZCC	Islam 2)	Tschinkel & Tschinkel 3)	Present work 4)
1	Pressure fed kerosene burner	P_{max} (kW) P_{max}/P_{min} η (av) %	-- -- 43,5	-- -- 27,5	--	2,6 3,1 52,1	1,8 4,9 56,2
2	Variable wick kerosene burner	P_{max} (kW) P_{max}/P_{min} η (av) %	-- -- 22	-- -- 37,7	1,4 -- 43,2	1,0 1,1 40,0	1,5 4,5 46,1
3	Fixed 5) wick kerosene burner	P_{max} (kW) P_{max}/P_{min} η (av) %	--	--	-- -- 29,1	2,2 1,4 34,7	1,8 5,2 43,0
4	Gas burner	P_{max} (kW) P_{max}/P_{min} η (av) %	--	--	1,4 -- 58,6	1,6 4,4 55,0	1,9 5,3 57,3
5	Pool burner	P_{max} (kW) P_{max}/P_{min} η (av) %	--	--	--	--	1,3 8,0 61,0

Notes: 1) Efficiency averaged over two extreme values.
2) Efficiency averaged over different burners and pan sizes.
3) Efficiency averaged over different power levels and pan sizes.
4) Efficiency averages obtained from table 6.6 for each class of stoves.
5) Prabhakar & Axe of the present study belong to this category.

Sources: Fiji and NZCC obtained from Siwatibau (1981)
Islam from Islam (1980)
Tschinkel & Tschinkel from Tschinkel and Tschinkel (1975)

More detailed comparison between the present work and the Tschinkel & Tschinkel work is possible. First, we show a plot of their tabulated data showing the variation of efficiency with power level in fig. 6.6. These should be compared with present results in fig. 6.2. In both cases the variations are not that large. The gas stove we tested in principle could be stated to have an efficiency independent of power. Tschinkel and Tschinkel data do show an increasing efficiency trend with power level. But this has to be balanced by the observation that the noise in the data is of the same order of magnitude as the total change. The range of power of the wick stoves Tschinkel & Tschinkel tested was too small to make any comment. In fact the power range attained in the Tunisian tests is consistently lower than the ones realized in the present test programme. It is not clear whether this is attributable to the stove designs employed in the Tunisian tests.

6.5. Fuel consumption estimates for cooking

In practical terms one is not interested in the thermodynamic efficiency of a stove, but the amount of fuel it consumes to perform a specified cooking task. We have repeatedly pointed out in the preceding pages, that efficiency is not the sole indicator for achieving fuel economy; the latter is also strongly influenced by the turn-down ratios, or the ratio P_{max}/P_{min}. The information obtained in the present programme can be made use of in deriving estimates of fuel consumption. In this section we shall present the results of such calculations. The details of the calculation procedure are relegated to Appendix 5.

The cooking task has been identified as that of cooking rice and a lentil-cum-vegetable sauce. This choice has been made since it involves substantial periods of simmering. For the calculations carried out here, the simmering durations have been assumed to be $\frac{1}{2}$ and 1 hour for the rice and sauce respectively. The initial heating up period (till the food mixture reaches boiling point of water) is assumed to occur at P_{max} and simmering to occur at P_{min}. In cases where efficiencies are known at P_{max} only, we have used the same value for P_{min}. This is not expected to make much difference since efficiency does not strongly depend on power level of the fire.

The calculation procedure and the data used are similar to the one employed by Krishna Prasad (1983). These are indicated in Appendix 5. The calculations have been carried out for three classes of stoves - a hypothetical set to suggest the importance of P_{max}/P_{min}, the wick stoves and pressure/gas stoves tested in this investigation. The actual quantities of food used in the calculations correspond to the pan sizes and $\frac{3}{4}$ of its volumetric content. The results of the calculations are presented in table 6.8. The table shows the computed fuel consumption quantities (m_{fuel}) in grams and the specific fuel consumption (m_{fuel}/m_{food}) in grams of fuel per kilogram of cooked food.

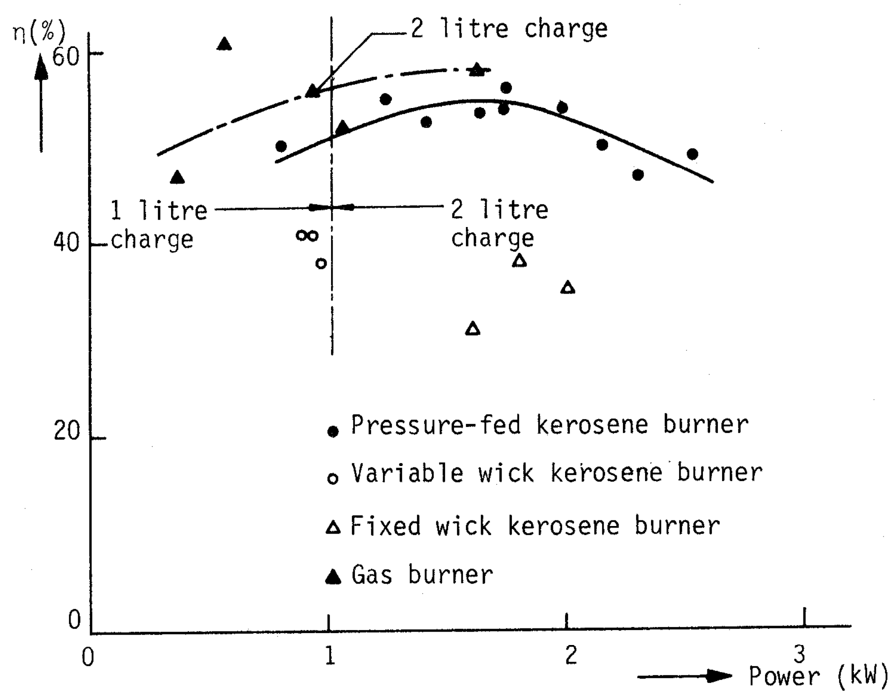

Fig. 6.6. Plot of efficiency vs. power from the tabulated data of Tschinkel & Tschinkel (1975)

Table 6.8. Fuel consumption estimates for different stoves

Sl. no.	Stove type	P_{max} kW	P_{min} kW	η %	Pan ϕ cm	Meal	m_{fuel} g	$\frac{m_{fuel}}{m_{food}}$ (g/kg)
THREE HYPOTHETICAL STOVES								
1	S_1	3	0,75	45	24	I	180	39
2	S_2	3	0,5	45	24	I	145	31,5
3	S_3	3	0,75	60	24	I	162	35
WICK STOVES								
4	Ashok	1,95	0,64	48	18	II	127	53
5	Ashok	2,20	1,95	48	18	II	313	130
6	Ashok	2,20	1,95	48	20	III	322	104
7	Nutan	1,11	0,22	44	18	II	71	30
8	Nutan	1,88	0,75	44	18	II	146	61
9	Lark	1,35	0,34	41	18	II	91	38
10	Lark	2,8	1,81	41	18	II	299	125
11	Lark	2,8	1,81	61	24	I	310	67,5
12	Swan 14	1,3	0,3	46	18	II	81	34
13	Hock	1,8	0,35	43/36	18	II	90	37,5
PRESSURE AND GAS STOVES								
14	Annby	3,6	0,4	57	24	I	115	25
15	Propane burner	3,5	0,4	55	24	I	110	24
16	Camping Gaz	1,3	0,4	58/60	18	II	83	35

Note: For the definitions of Meals I, II & III see Appendix 5.

We first consider the results of three hypothetical stoves. These results clearly establish the important role of P_{min} in determining the fuel economy for these cooking tasks. S_2 with a modest efficiency but a high turn-down ratio shows the least specific fuel consumption.

We next turn to the wick stoves. Both Ashok and Nutan show the beneficial effects that a low P_{min} will have on the fuel economy. The dramatic effect that proper wick setting can have on fuel consumption is seen with the results calculated for Nutan. The fuel consumption with the wick set according to manufacturer's recommendation is two times the value obtained according to the wick setting done in this work! In fact Nutan with our wick setting produces the lowest specific fuel consumption among the wick stoves listed in table 6.7.

In general large quantities of food cooked result in smaller specific fuel consumption, as can be seen from the results on the Ashok stove with a 20 cm diameter pan. The results on the Lark show that increased pan size with a low turn-down ratio wick setting produces the same specific fuel consumption as the one with a smaller pan (lower efficiency, smaller quantity of food) but with a higher turn-down ratio.

Of course one can object to time penalties involved in our wick setting procedure. In fact for the cooking regime chosen here, the Nutan stove with the high power setting shows almost the same time as that for the low power setting (less than a minute difference in 117 minutes for the two cases). It does make a difference in a case like bringing a litre of water to boil for making tea. The high power setting will do this job in about 7 minutes while the low power setting takes about 11½ minutes. This does not appear to be an enormous penalty at least according to us. Whether such a wick setting will carry out tasks like deep frying, we have not been able to establish in this study.

Among the stoves for which calculations are presented in table 6.8 Annby and the propane burner provide equal fuel economies while the camping gas shows inferior specific fuel consumption compared to both Nutan and Swan 14.

These calculations also help establish the frequency with which the tanks require refilling. These can be calculated with the tank capacities known for different stoves. These are shown tabulated in table 6.9. Two or more numbers in the last column correspond to more than one entry in table 6.8.

An important consequence of table 6.9 arises in connection with the Camping Gaz Feu R. An idea, that is useful to consider for overcoming the problems of kerosene supply and the poor efficiency (?) of wick stoves, is to replace both of them by stoves of the Camping Gaz type with gas as fuel. This approach is particularly attractive in view of the practice of flaring gas by many refineries. The main reason for this practice is the nonavailability of the gas cylinders in sufficient quantities at a price that could be afforded by individual domestic users. The gas tanks used by camping gas stoves* could be refilled and are much cheaper. However, the calculations in table 6.9 suggest that these cylinders need to be refilled every other day or maybe even every day. This is quite a chore for the user if she/he needs to go to the filling station every other day or so. (This situation sounds more like the task of fuel collection in rural areas!). Of course the whole process

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* Camping Gaz Bluet uses throw-away canisters and barely meets a day's gas supply for cooking and we do not believe that system to be practicable for domestic use.

can be assisted greatly if door to door sale of gas could be organized with the help of mobile gas tanks in a manner similar to what is being done for kerosene now in many developing countries. This might prove a useful approach to utilize a resource that is being wasted at present. This requires a certain amount of market study supported by some engineering work on mobile gas storage tanks particularly with reference to their capacity consistent with specified safety standards.

Table 6.9. Refilling frequency of stoves

Sl. no.	Stove type	Tank capacity (kg)	Number of meals
1	Ashok	2	15/6/6
2	Nutan	1,6	21/5
3	Lark	0,9	10/3/5
4	Swan 14	0,8	9
5	Hock	1,3	14
6	Annby	0,4	3
7	Propane burner*	10	78
8	Camping Gaz Feu R	0,5	5

* The standard gas cylinder capacity has been used.

A final aspect that is of interest in this section is to have some idea about the reliability of the calculations presented in table 6.8. This requires experimental evidence and it was not contemplated during the course of the present work to carry out any cooking experiments. At the time of this writing the only cooking tests known to the authors was that of Siwatibau (1981). From the details provided by Siwatibau, it is possible to estimate the fuel consumption using the method outlined in Appendix 5. The details of this calculations along with the data of Siwatibau are also included in this appendix. The calculation procedure overestimates the fuel consumption by about 16%. The agreement should be judged very good considering the simplicity of calculation procedure and unreliability of some of the data used in the calculation procedure.

6.6. Rating of stoves tested in the study from the consumers' point of view

Stoves are consumer products used in every kitchen and are operated not necessarily by technical experts. In addition the user is not merely interested in the fuel economy and the speed of cooking. The user's interest includes many other aspects which are not related to the above two. While the work presented in this report is a product of effort in an engineering laboratory, we have tried to imagine ourselves to be the users and list several criteria to judge the different stoves. In addition two of the authors (Sangen and Sielcken) who carried out the experiments carefully maintained a journal of the experiences they encountered while operating the stoves. On the basis of these two sets of separate experiences, the following list of criteria has been evolved.

1 Cost
2 Fuel economy
3 Sturdiness of construction
4 Mechanical construction quality
5 Storage tank temperature
6 Pan seating
7 Regulation ease
8 Ease of extinction of the stove
9 Pan cleanliness
10 Ease of refilling
11 Noise

This list has been used to construct table 6.10. Two factors must be borne in mind while using this table. Our experience with these stoves is the sum total of 12 man weeks collected during a very short period. Secondly, much of the judgement is quite subjective. In particular we do not purport to be a consumers' advisory council. We have no special qualifications in that field of enquiry. Thus our intention in constructing the table is simply to put up a sign-post of warning: the abstract arguments of fuel economy are inadequate to judge the "quality" of a stove! We will leave the reader with the table without further comment. However, apart from the quality of the stove, the manner in which the stove is used plays an important role in determining the fuel consumption. Fig. 6.7 shows a publicity poster from Sri Lanka which clearly illustrates the number of simple steps people could take to achieve fuel economy with a given stove design.

From an appearance point of view, the Swans, Divyajyoti and Hock look very neat among the wick stoves tested. In particular the Swans look exceptionally well made for the price one pays. Among the pressurized stoves tested the Annby and the Peak 1 are compact and have a neat appearance. Among the gas stoves, the propane gas burner looks quite clumsy.

A final point to be mentioned in this connection is that instruction manuals/leaflets were not available to the authors for all the stoves procured. Where they are available, not all of them mentioned fuel consumption rates, pan sizes to which the stoves are most suited and other information relevant to the users.

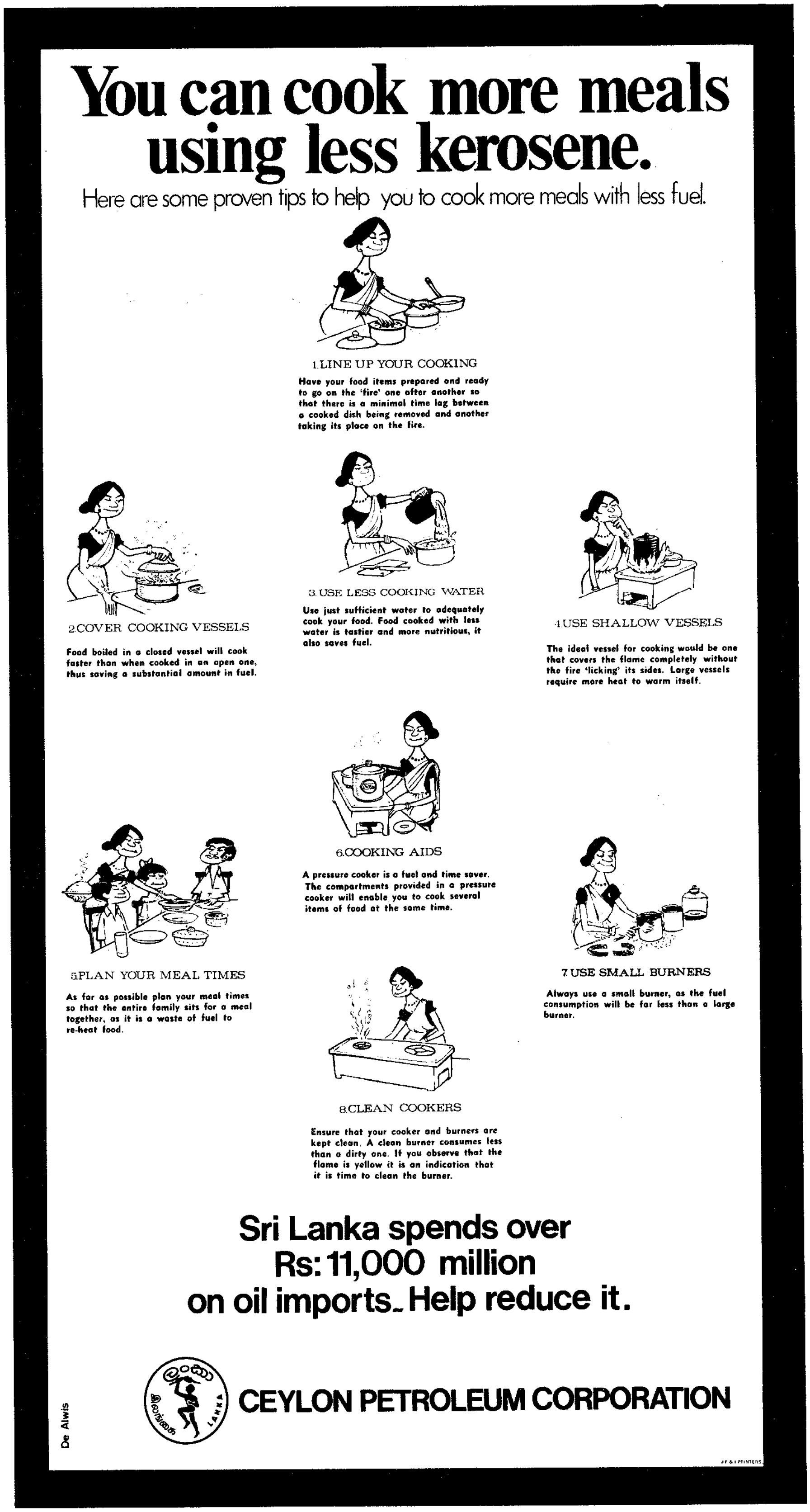


Fig. 6.7. Publicity poster from Sri Lanka to promote fuel savings.

Table 6.10. A rating chart for stoves tested

Sl. no.	Stove	Identi-fication no.	Cost (US $)	Fuel economy [1]	Sturdiness of construction [2]	Mechanical construction quality [2]	Storage tank temperature [3]	Pan seating [4]	Ease of regulation [2]	Ease of extinction [2]	Pan cleanliness [5]	Ease of refilling [5]	Noise [5]
1	Ashok	7	12,00	-	+	+	-	+	□	+[6]	+	+	+
2	Nutan	8	7,25	+	+	+	-	+	□	+[6]	-	+	+
3	Surya	11	4,50		+	+	-	-	□	□	+	-	+
4	Divyajyoti	12	7,50	-	+	+	-[7]	-	□	+	+	+	+
5	Hock	22	8,00	+	+	+	-	+	□	□	+	-	+
6	Ideal	25	18,50		+	-	-	-	□	□	+	+	+
7	Swan 14	6	5,50	□	+	+	-	+	□	□	+	-	+
8	Swan 20	36	6,25	□	+	+	□	+	□	□	+	-	+
9	Lark	35	9,00	□	+	+	-	+	□	□	+	-	+
10	Prabhakar	13	15,50	+	+	+	+	□	-	-	+	+	+
11	Axe	24	24,00	□	+	+	+	+	-	-	+	+	+
12	Primus 505	14	45,00	-	+	+	-	□	+	+	+	+	+
13	Annby	15	60,00	+	+	+	-	□	+	-	+	+	+
14	Primus	19	45,00	-	+	+	-	□	+	+	-	+	-
15	Primus (USSR)	38	9,00	□	+	+	-	□	+	+	-	-	-
16	Peak 1	16	50,00	□	+	+	□	□	+	+	+	+	+
17	Optimus 77A	18	25,00	+	+	+	-[8]	□	-	+	+	+	+
18	Camping Gaz Feu R	20	24,00	-	+	+	+	□	+	+	+	+	-
19	Camping Gaz Bluet	21	10,00	□	+[9]	+	+	□	+	+	+	+	-
20	Propane burner	39		+	+	+	+	□	+	+	+	+	+

1) Fuel economy based on: - $P_{max}/P_{min} < 3,3$; □ $3,3 < P_{max}/P_{min} < 5,0$; + $P_{max}/P_{min} > 5,0$.
2) - poor; □ satisfactory; + good.
3) - hot; □ moderate; + just warm.
4) - nonadjustable; + adjustable; □ irrelevant.
5) - unsatisfactory; + satisfactory.
6) Flame extinguisher comes with the stove.
7) Kerosene vapour escapes from tank.
8) Pool burner.
9) Comes with an extra base plate.

7. CONCLUDING REMARKS

The preceding sections of the report present test results on three classes of stoves, namely wick stoves, pressurized stoves and gas stoves. The principal design features of wick stoves made in several countries (India, Indonesia, Korea, Malaysia, and People's Republic of China) do not show significant differences. Similar is the case with other stoves tested.

Three factors are important from process considerations. These are maximum power (P_{max}), minimum power (P_{min}) and the efficiency. All these quantities were measured for 18 stoves during the course of the investigation. The power rating of all stoves tested with the exception of 3 is under 2 kW. However, the minumum power varies by as much as a factor of four for the stoves tested. The efficiency of the wick stoves on the average appears to be about 46%. Nutan with an efficiency of 63% and Divyajyoti with an efficiency of 24% are the exceptions. The pressure stoves have an efficiency of 56%. The gas stoves have an efficiency of 57%. The petrol burner Peak 1 and the gas burner Camping Gaz Feu R have the highest efficiency (67%) among the stoves tested.

Two aspects of the problem, which we have encountered in our studies on woodstoves, have a decided influence on the fuel economy of a stove. The efficiency of a stove is strongly influenced by the pan size (and presumably shape). The second is the turn-down ratio. The latter is strongly influenced by the initial setting of the wick in wick stoves. The report presents quantitative evidence in support of these assertions.

A comparison of the results obtained in the present study with the earlier studies generally confirm the overall picture we have drawn here. Of course there exist puzzling differences among the several details which we can not explain. A suggestion we make in this connection is that it would be helpful if the manufacturers concerned could be persuaded to fund an existing institution to carry out systematic studies and evolve towards a standardized procedure of testing stoves. This institution could also provide advice to the public as to the quality of different stoves on the market.

In general we would like to state that wick stoves are good value for money one pays. Handsome dividends can be obtained by some relatively straightforward engineering work. We make two simple suggestions which will assist in realizing the full potential of these stoves. The first concerns putting a mark on the stove body next to the control lever. This marker has to correspond to the position of the lever with the wick setting recommended by the manufacturers of Nutan and Ashok. With a warm stove, the lever could be pushed down to realize the low powers that we have obtained in this investigation. It is preferable to see that wicks at the lowest position of the lever maintain a steady flame. This means that an extinguisher (like the ones provided by Ashok and Nutan) is mandatory for extinguishing the flames. The second suggestion stems from the first. The rack of the rack and pinion arrangement for moving the wick probably needs to be extended by about 5 mm to realize the requisite low power without seriously affecting the P_{max}.

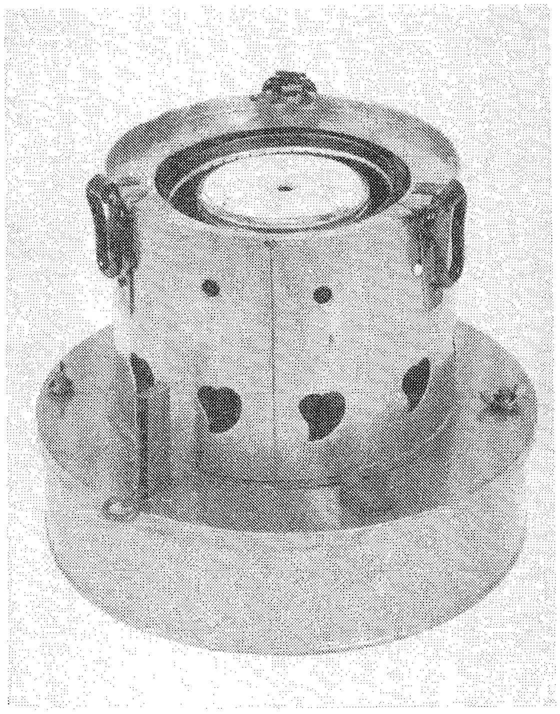
It is our belief that a certain level of research on several aspects can be expected to make the wick stoves quite competitive with gas stoves at least in a technical sense. The wick material characteristics, flame holder and air-holes proportioning, the position of the pan with respect to the flame holder and power density influence on the stove performance are four aspects that straightaway come to our mind.

The pressure stoves, as far as we can see now, do not hold much prospect as a big competitor to wick stoves since they possess the main disadvantage of a kerosene stove (the smell!) with the added discomfort of noise. Of course they are much more expensive. From a purely technical point there is very little to be said against a gas stove.

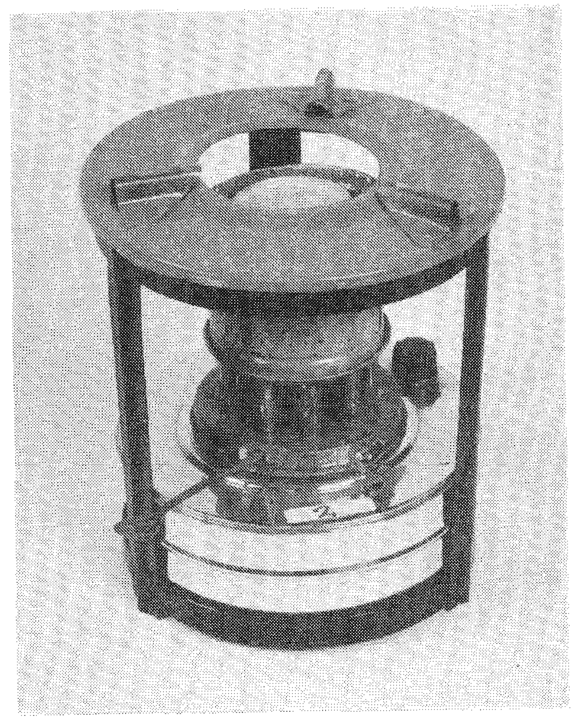
APPENDIX 1. INVENTORY OF THE PROCURED STOVES

Underneath each photograph the brand, country of manufactury, country of purchase and the price (rate of May 1983) are mentioned respectively.

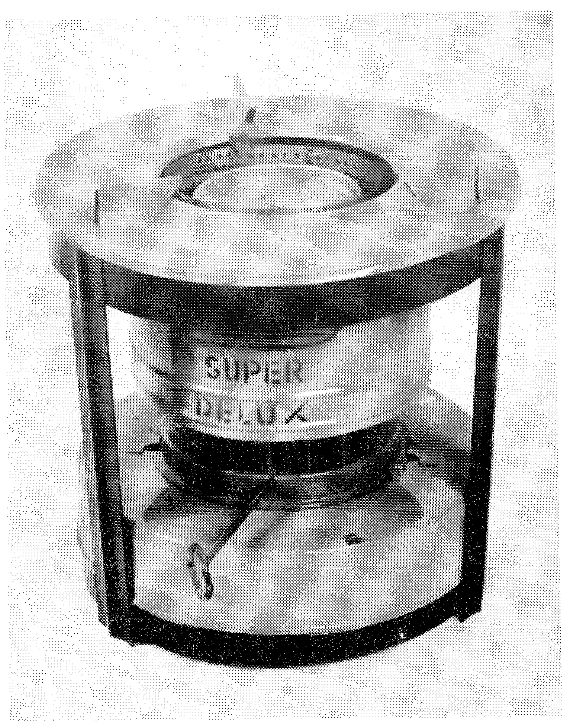
WICK STOVES



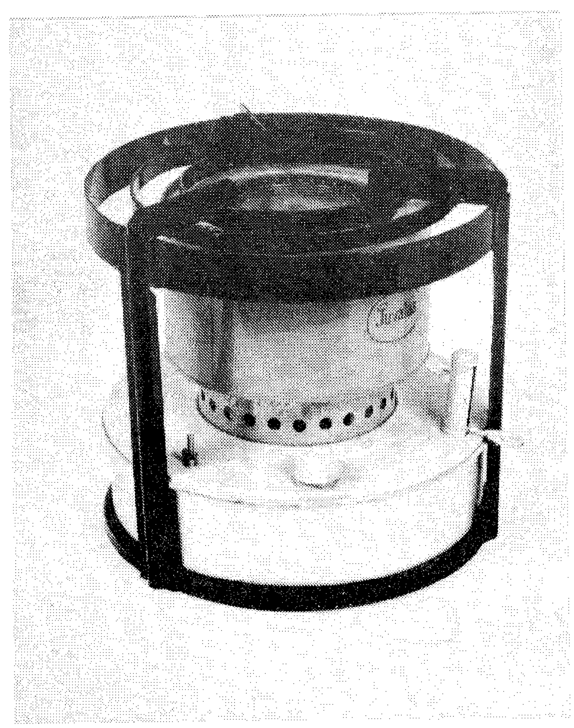
Stove 1. Sathya/?
India/$3,25



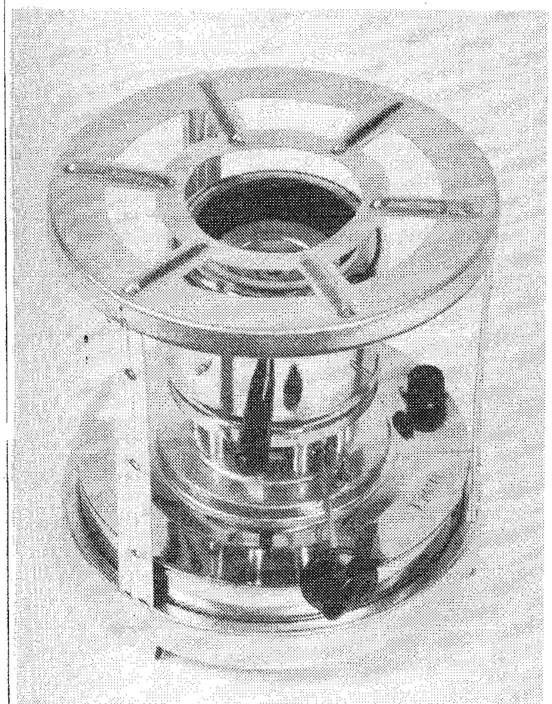
Stove 2. Pushya/India
India/$2,00



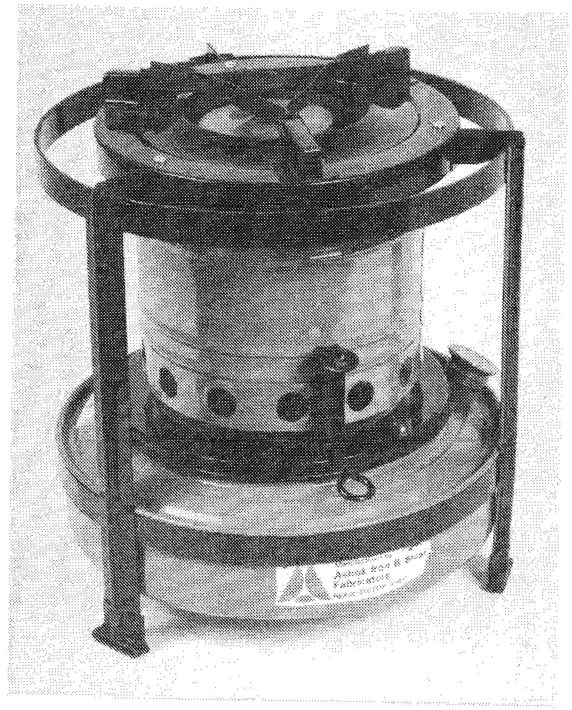
Stove 3. Umrao, super de luxe/India
India/$9,50



Stove 4. Juvalaa/India
India/$8,50

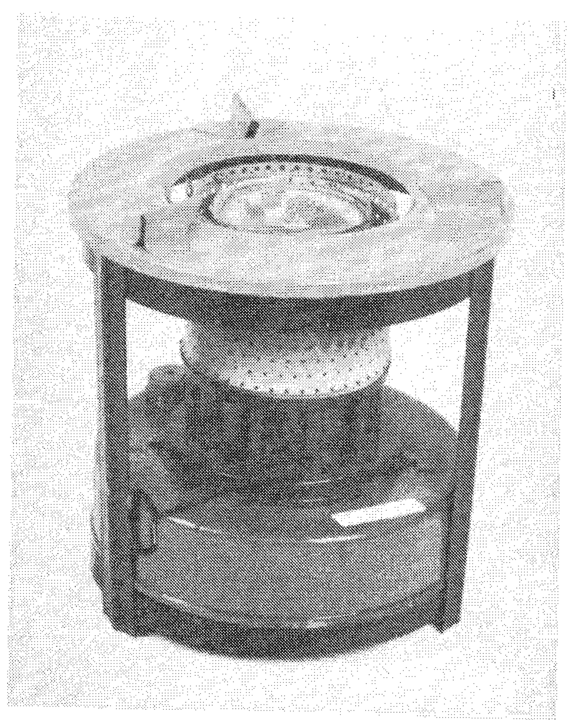


Stove 5. Morley, 10 W x SE/India
India/$12,50

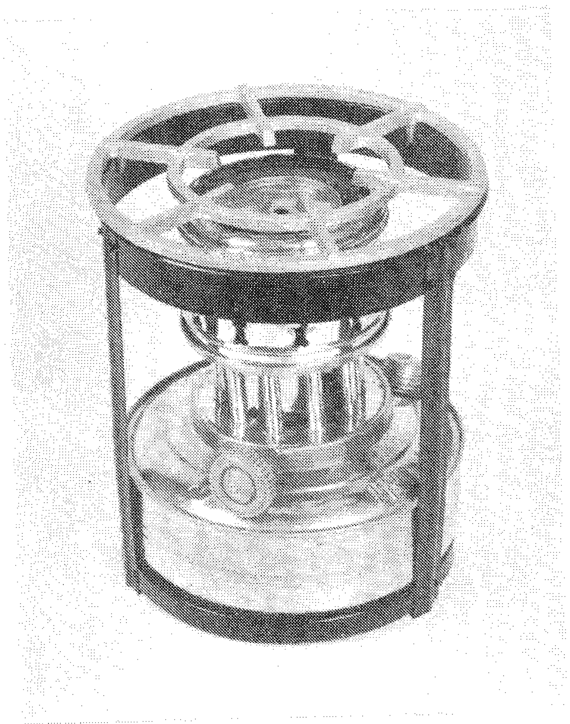


Stove 7. Ashok/India
India/$12,00

Stove 8. Nutan/India
India/$7,50

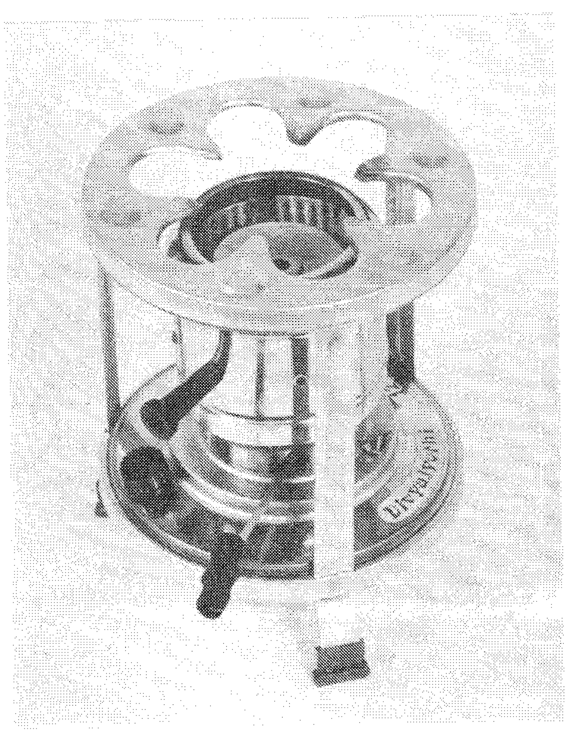


Stove 9. Umrao/India
India/$3,00

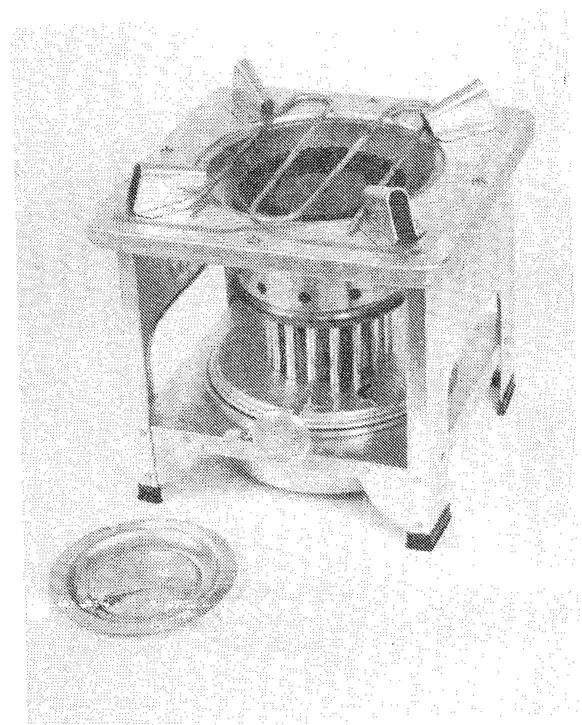


Stove 10. Devi/India
India/$7,25

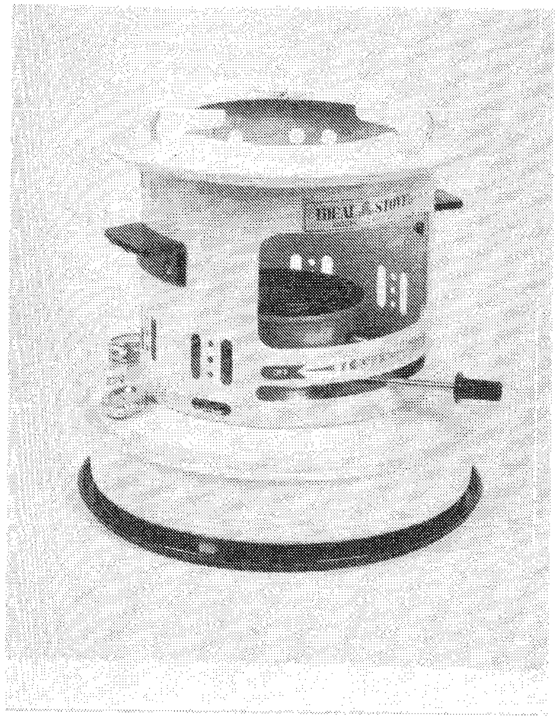
Stove 11. Surya/India
India/$4,50



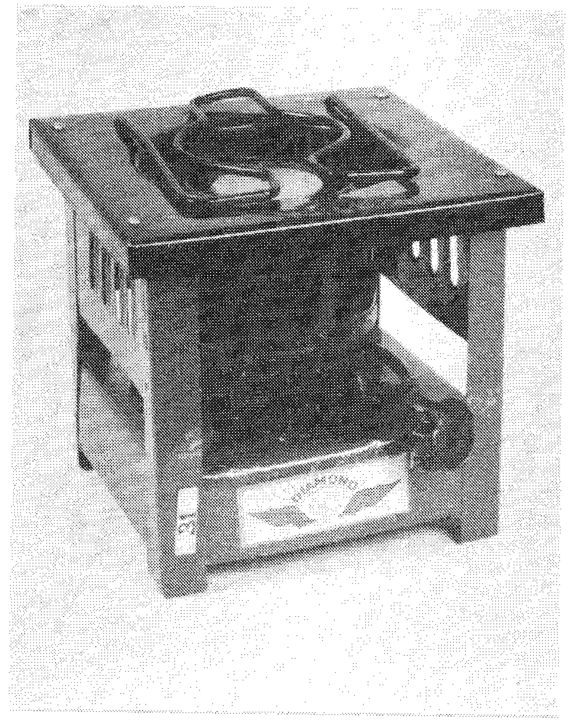
Stove 12. Divyajyoti/India
India/$7,50



Stove 22. Hock/Indonesia
Indonesia/$8,00

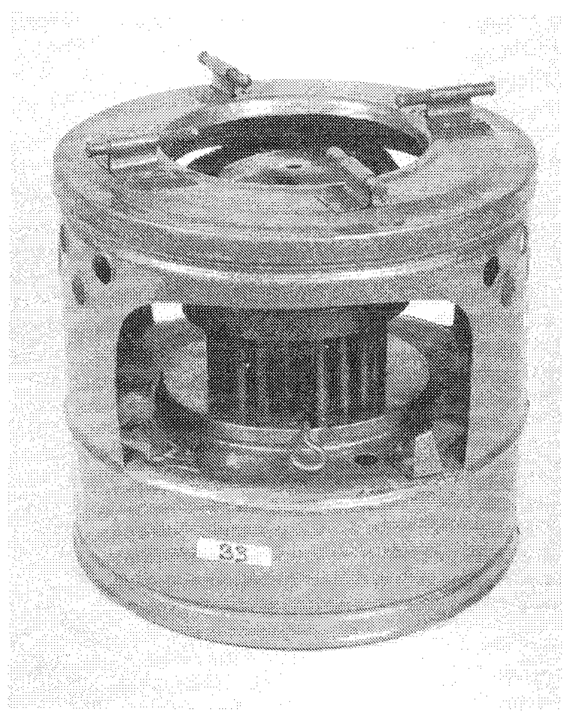


Stove 25. Ideal Stove, model IKS 160/Korea
Indonesia/$18,50

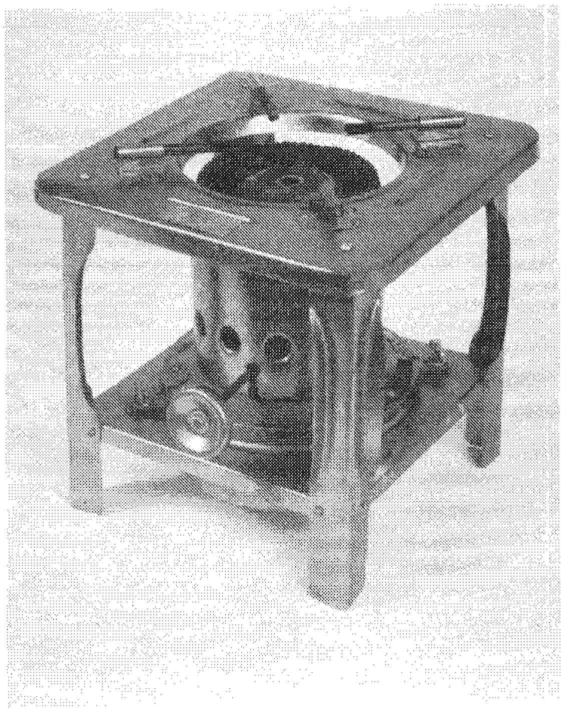


Stove 31. Diamond, model 6411/?
Indonesia/$2,50

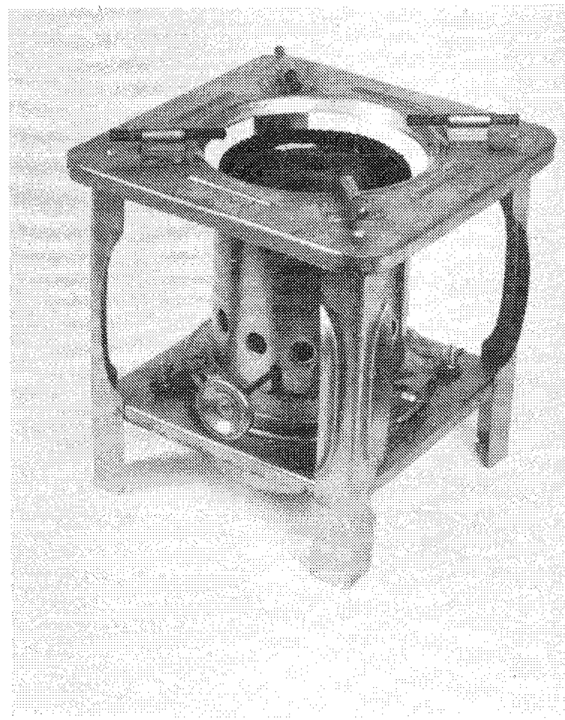
Stove 32. Double Butterfly Brand/China
Indonesia/$9,50



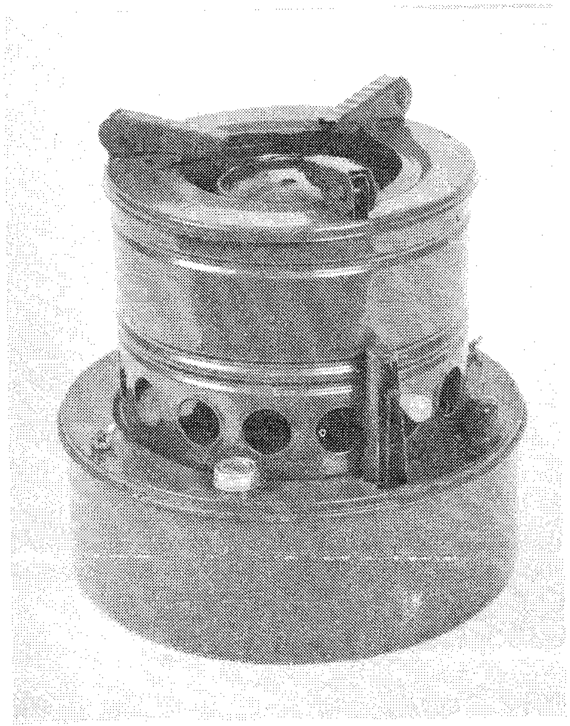
Stove 33. Dinoyo/Indonesia
Indonesia/$3,00



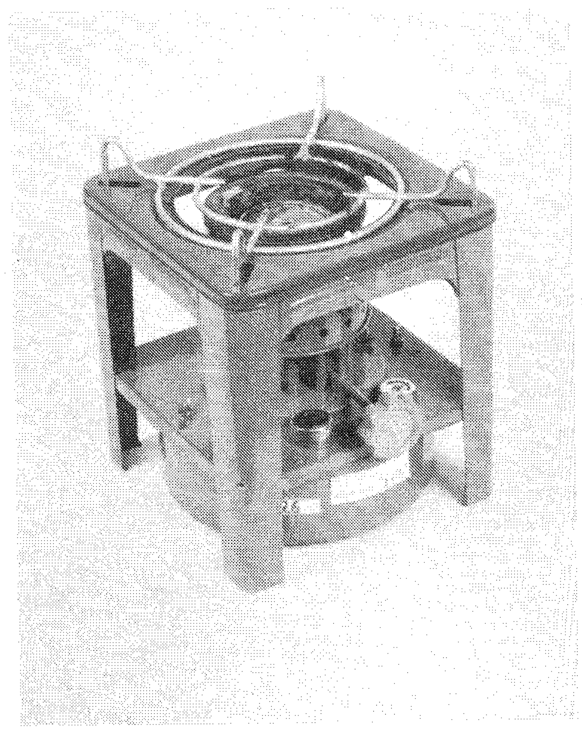
Stove 6. Swan, 14/?
Indonesia/$5,50



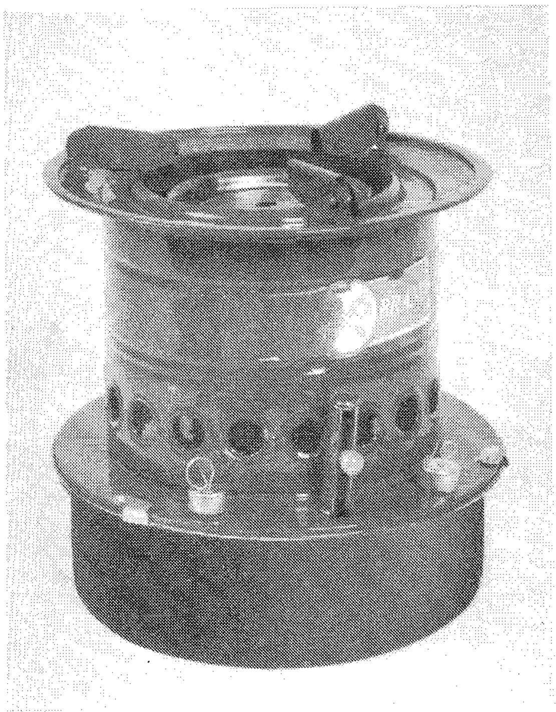
Stove 36. Swan, 20/?
Indonesia/$6,25



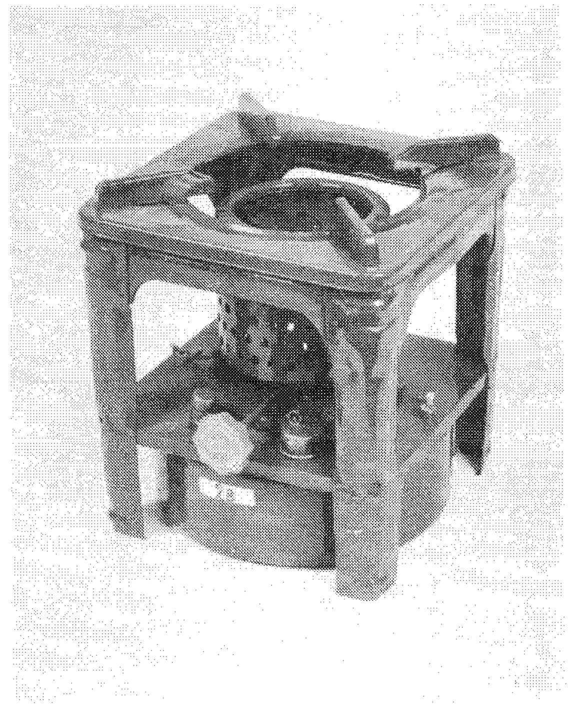
Stove 23. Axe Brand/Malaysia
Singapore/$6,50



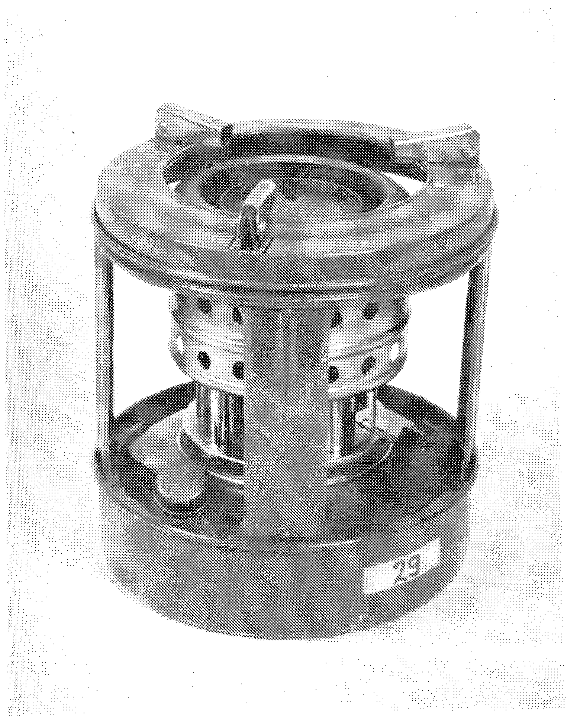
Stove 26. Axe Brand, no. 106/Malaysia
Singapore/$11,00



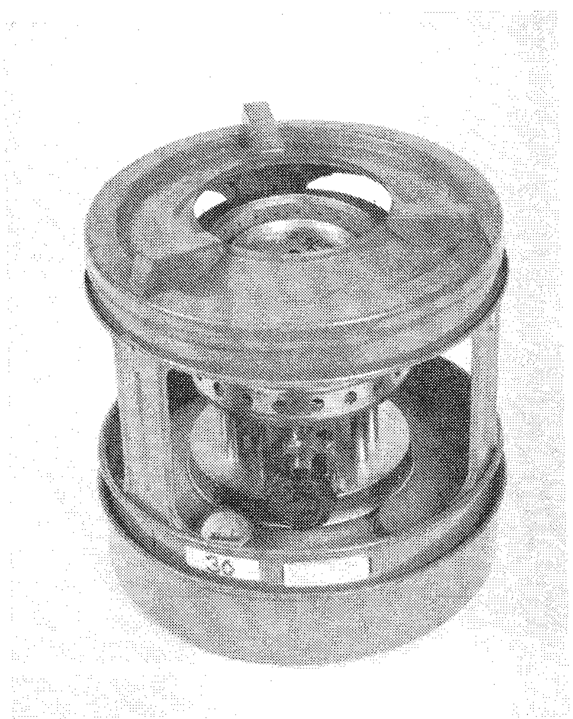
Stove 27. Axe Brand/Malaysia
Singapore/$7,50



Stove 28. Rhino Brand/?
Singapore/$10,00

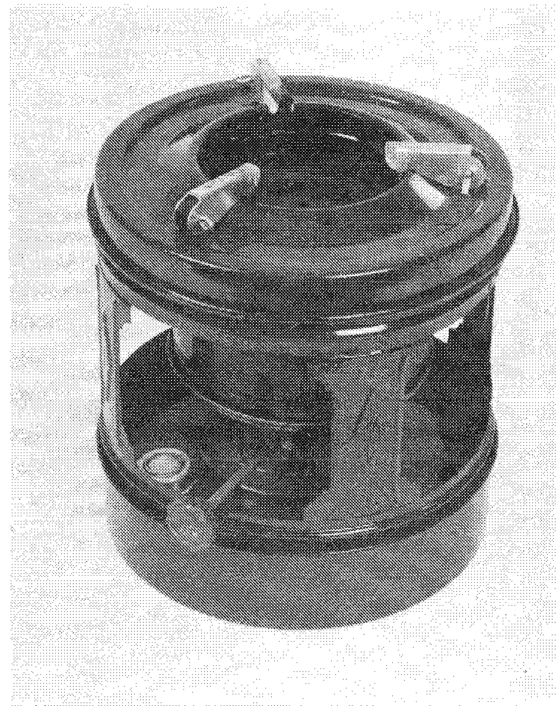


Stove 29. Triangle/China
Singapore/$6,00



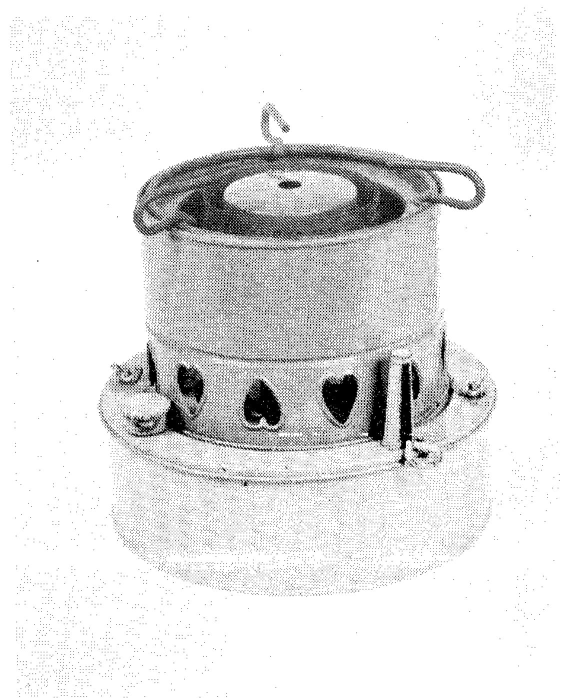
Stove 30. Triangle, no. 163/China
Singapore/$11,00

Stove 34. Triangle, no. 168/China
Singapore/$6,50

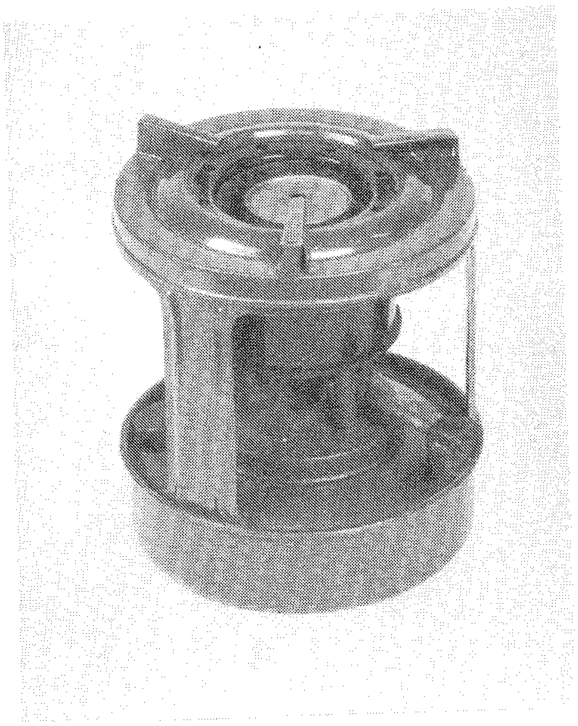


Stove 35. Lark, T733/China
Jemen/$9,00

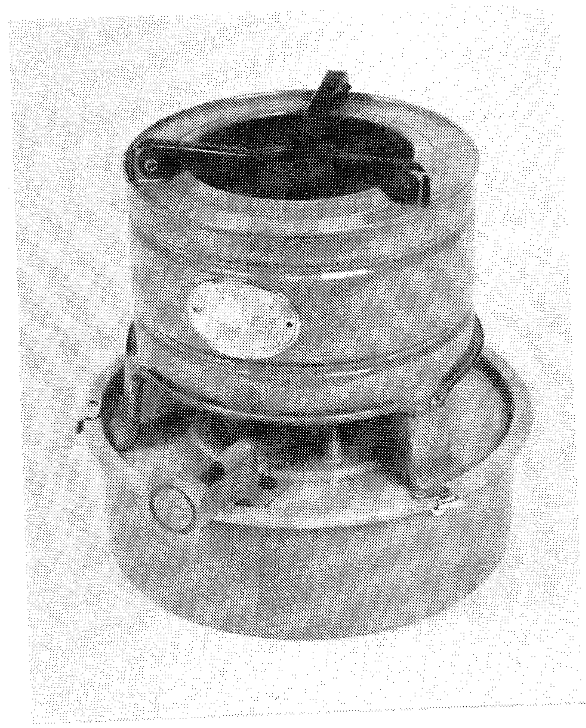
Stove 37. Floweret/China
Jemen/$9,00



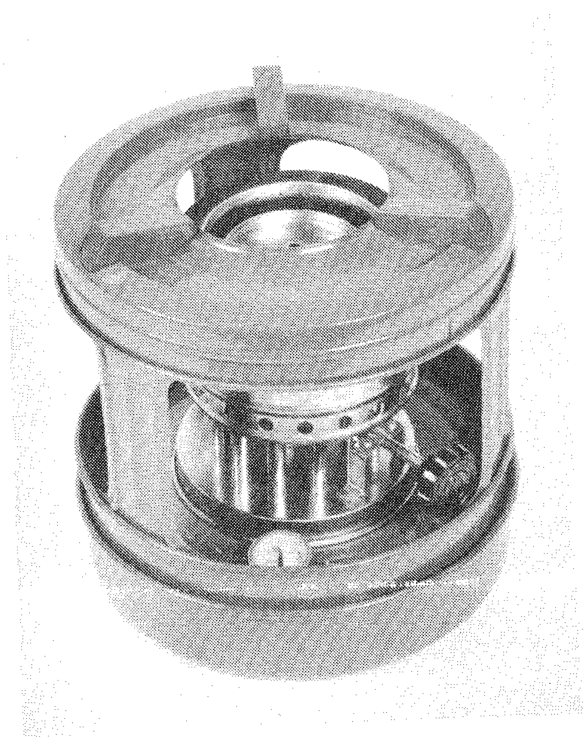
Stove 40. ?/?
Thailand/?



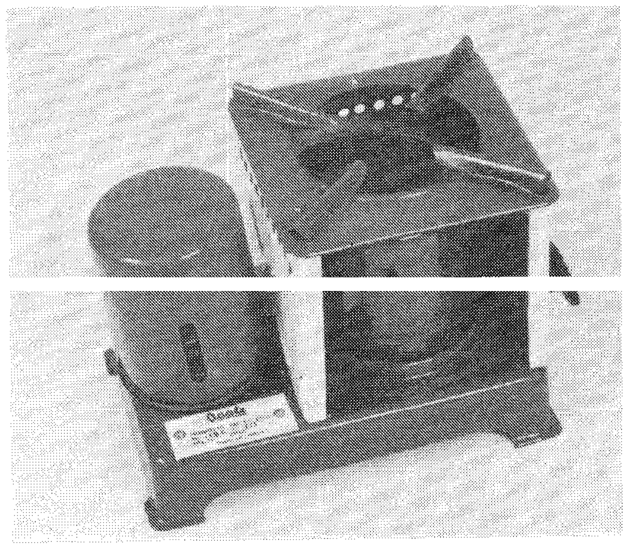
Stove 41. Double Rhomb, no. S743/China
Kenya/?



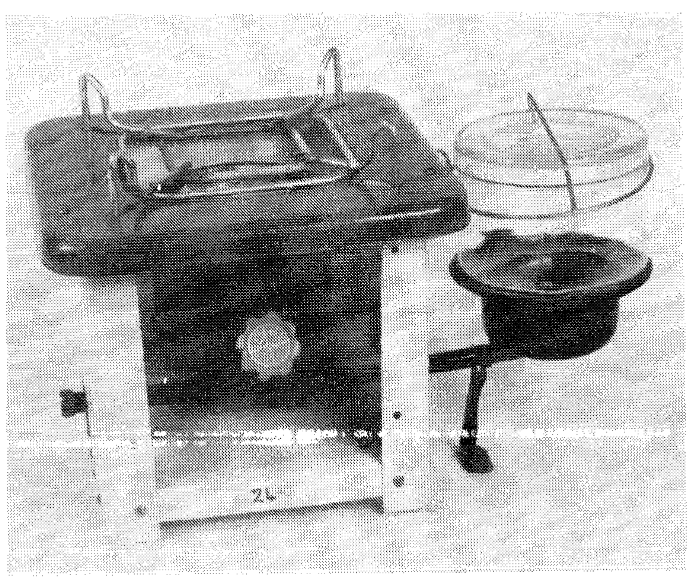
Stove 42. Wheel Brand, model 62/China
Kenya/$16



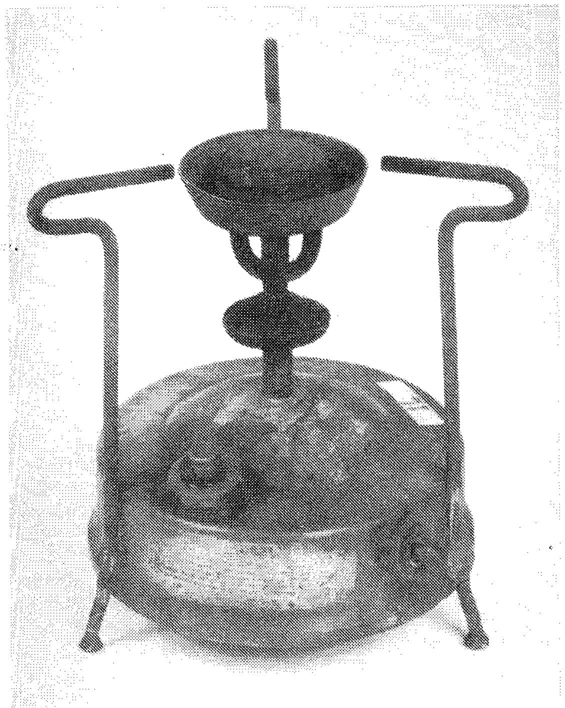
Stove 43. Triangle, no. 163/China
Kenya/?



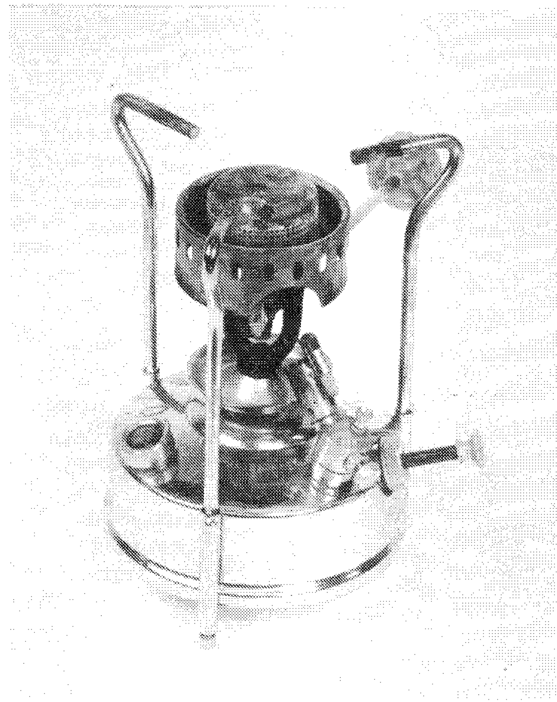
Stove 13. Prabhakar/India
India/$16,00



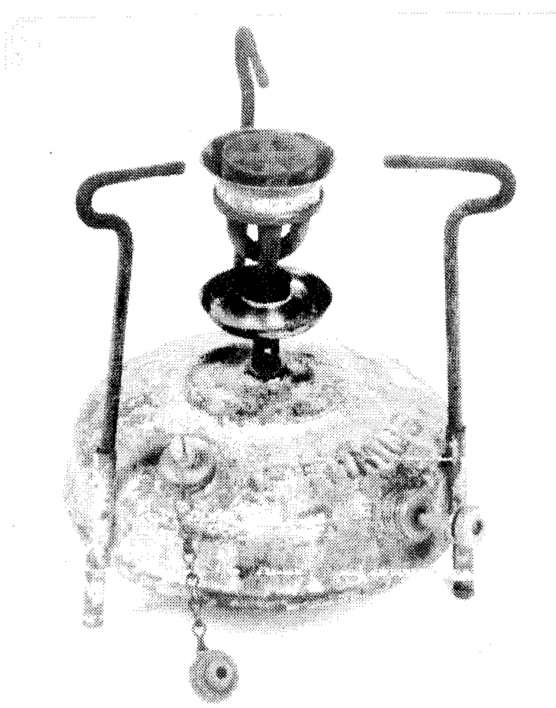
Stove 24. Axe/Malaysia
Singapore/$24,00



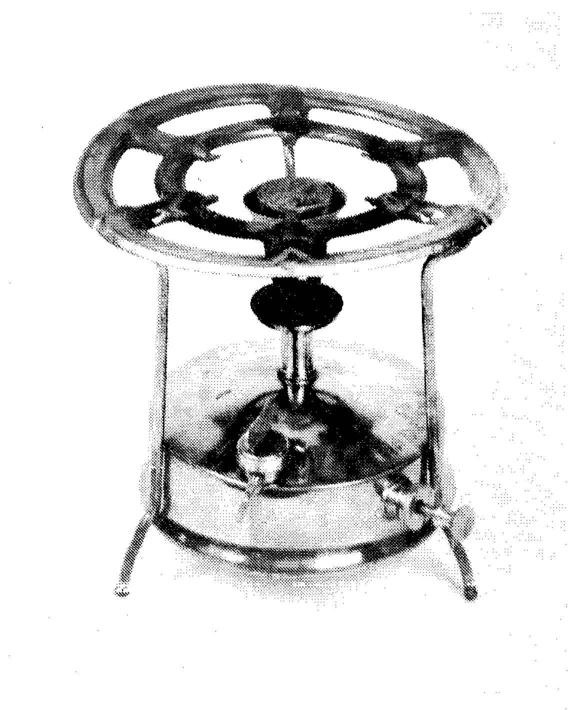
Stove 14. Primus 505/Sweden
Netherlands/$45,00



Stove 15. Annby 105/Korea
Netherlands/$60,00

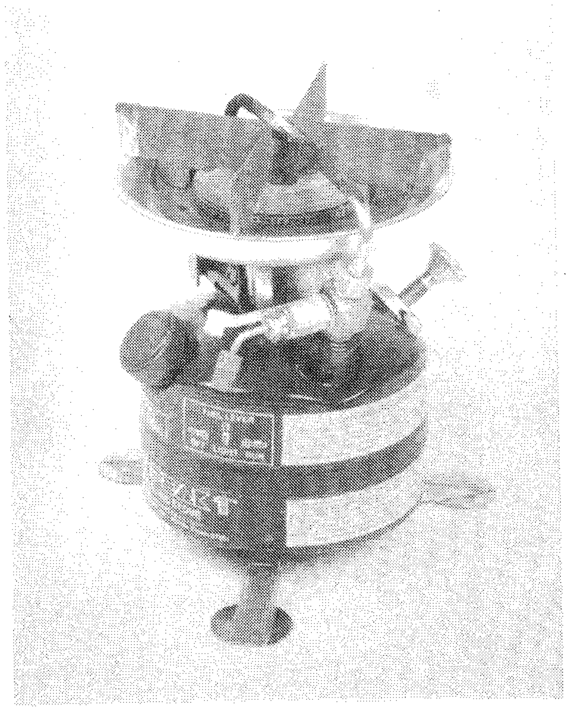


Stove 19. Primus/Sweden
Netherlands/$45,00

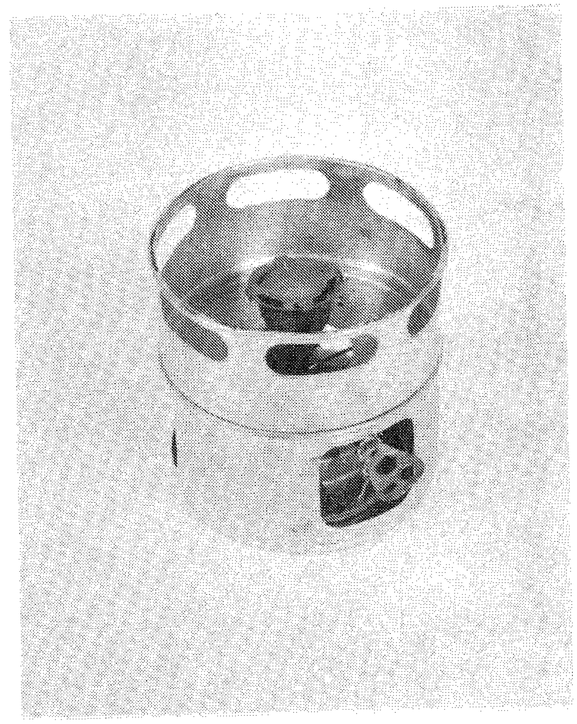


Stove 38. Russian Primus/USSR
Jemen/$9,00

PETROL STOVES



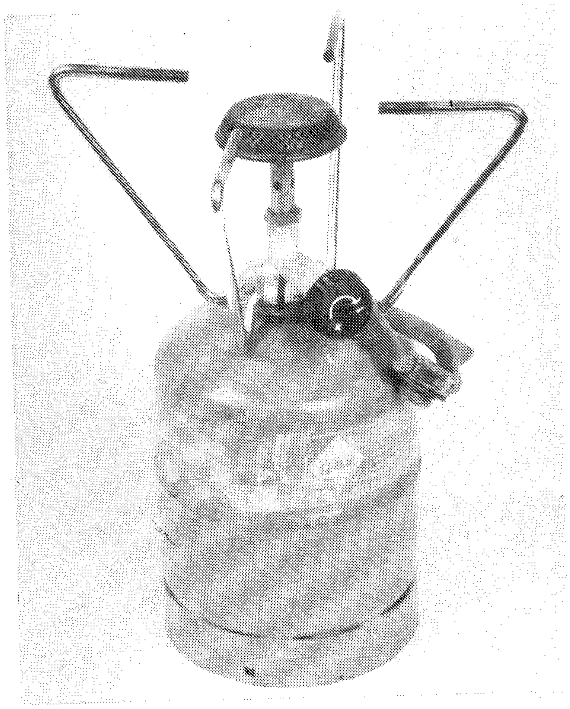
Stove 16. Peak 1, model 400/USA
Netherlands/$50,00



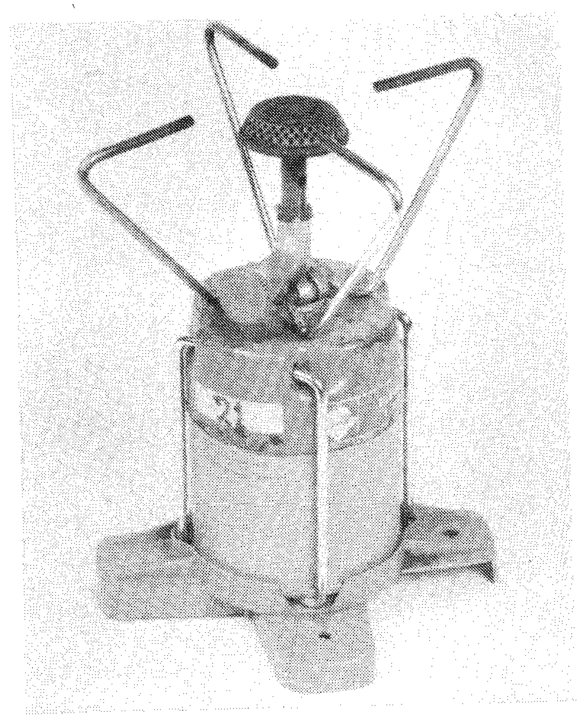
Stove 17. Svea 123/Sweden
Netherlands/$40,00

SPIRIT STOVE

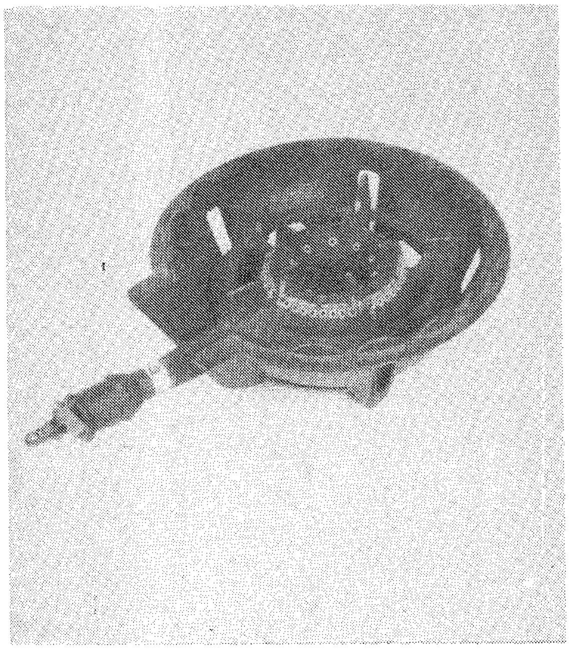
Stove 18. Optimus 77A/Sweden
Netherlands/$25,00



Stove 20. Camping Gaz, Feu R/France
Netherlands/$24,00

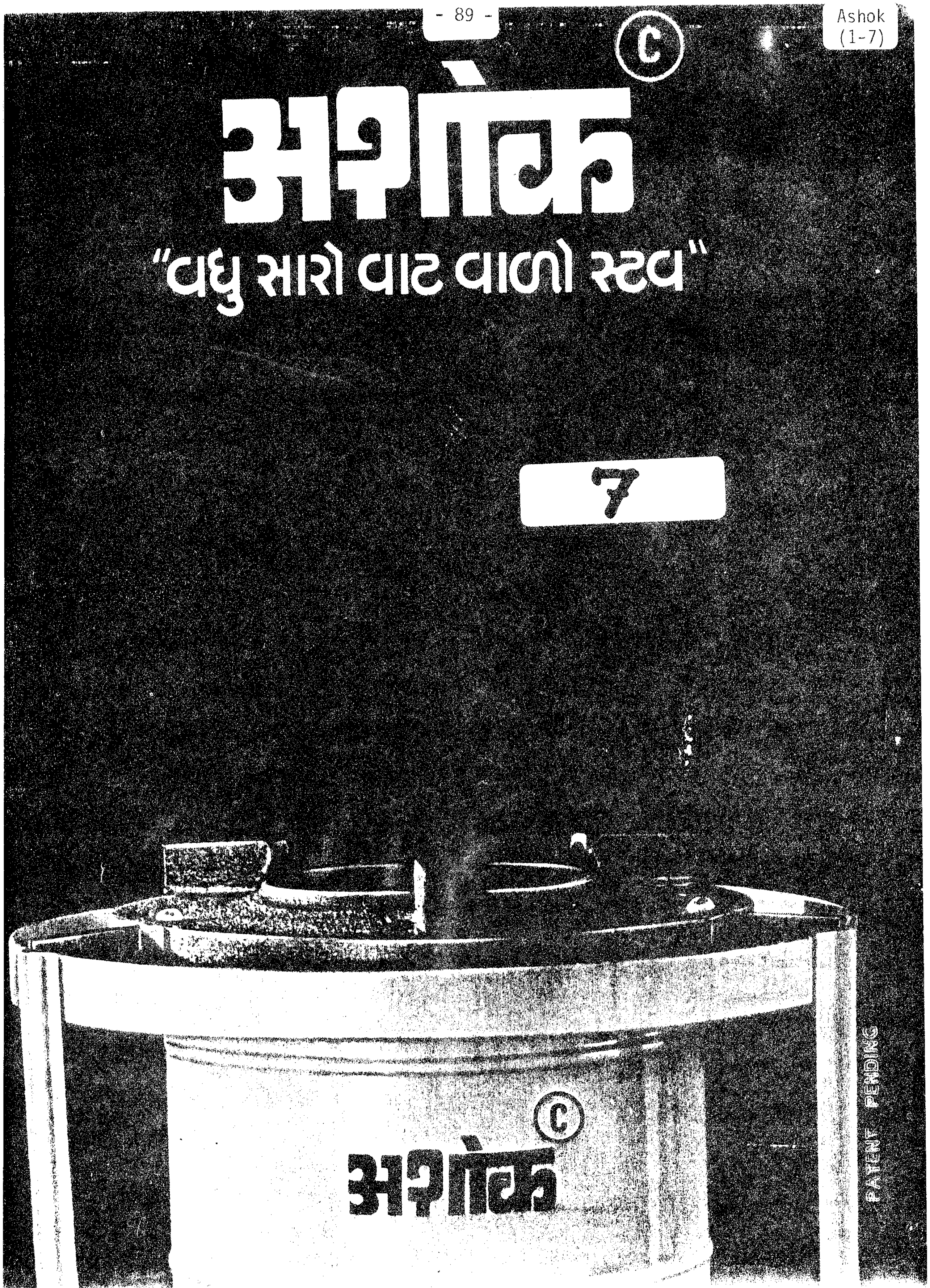


Stove 21. Camping Gaz, Bluet/France
Netherlands/$10,00



Stove 39. Propane burner/Japan
Thailand/?

APPENDIX 2. MANUFACTURERS' LEAFLETS


अशोक ©
"વધુ સારો વાટ વાળો સ્ટવ"
7
अशोक ©
PATENT PENDING

ASHOK IRON & STEEL FABRICATORS RAJKOT

ઉત્પાદક:
અશોક આર્યન્ એન્ડ સ્ટીલ
ફેબ્રીકેટર્સ
રાજકોટ ૩૬૦ ૦૦૨, (ભારત)

વેચાણ આયોજક:
મીરા ઉદ્યોગ,
નવડી પ્લોટ, રાજકોટ ૩૬૦ ૦૦૪ (ભારત)

ટેક્નીકલ સલાહકાર:
અશોક મશીન ટુલ્સ,
નવડી પ્લોટ, રાજકોટ ૩૬૦ ૦૦૪

"અશોક સ્ટવ" નો સરળતાથી ઉપયોગ કરવા અને ઉત્તમ કામગીરી મેળવવા અન્યત્ર આપેલ સૂચનો વાંચી જવા જરૂરી છે."

"અશોક સ્ટવ એક ઉડતી નજરે"

૧) પ્રકાર:- વાટવાળો દબાણ વિનાનો કેરોસીન સ્ટવ.
૨) ટાંકીની ક્ષમતા:- આશરે ૩ લી. કેરોસીન.
૩) વાટની સંખ્યા:- ૧૦ (દસ)
૪) કેરોસીન વપરાસનું પ્રમાણ:- ૧૪૦ થી ૧૬૦ ગ્રામ પ્રતિકલાકે.
૫) ઉપયોગી ઉષ્ણતા પ્રાપ્તિ:- ૯૪૦-૯૫૦ કિ. કેલેરી પ્રતિકલાકે.
૬) થર્મલ એફીસીઅન્સી:- ૫૮ થી ૬૦%

"અશોક સ્ટવ ની વિશિષ્ટતાઓ"

૧) અશોક સ્ટવ ઉચ્ચ ગુણવત્તા વાળા ટેસ્ટેડ મજબુત મટીરીઅલમાંથી બનાવવામાં આવતા હોય તેનો રોજીંદો વપરાશ સુગમ અને આનંદદાયક હોય છે.

૨) 'અશોક સ્ટવ' નો ઉપયોગ આપેલ સુચનાં મુજબ કરવામાં આવે તો ૨૦ થી ૩૦ ટકા કેરોસીન નો બચાવ થઈ શકે છે.

૩) 'અશોક સ્ટવ' ગેસનાં ચુલા પરથી જેટલો તાપ મેળવી શકાય તેટલો મળી શકે તે રીતે સુયોગ્ય અને સુંદર ડીઝાઈન તથા મન મોહક રંગોમાં બનાવવામાં આવેલ છે.

૪) 'અશોક સ્ટવ' પર નાના મોટા વજનદાર રાંધવાનાં વાસણો સહેલાઈથી ગોઠવી શકાય છે.

૫) 'અશોક સ્ટવ' ના સુંદર ડીઝાઈન કરેલા વાટ રેગ્યુલેટર વડે વાટને સહેલાઇથી ઉંચી નીચી કરવાથી જરૂરીયાત મુજબ ઓછો વતો તાપ મેળવી શકાય છે.

૬) 'અશોક સ્ટવ' એટલે મેશ નહીં— અસરકારક કંટ્રોલ અને બલ્યુ જ્યોત.

"સ્ટવ સળગાવવાની રીત"

૧) ટાંકીમાં પોણી ટાંકી સુધી ગરણી વડે કેરોસીન ભરો.

૨) પ્રથમ વખત જ્યારે સ્ટવ સળગાવવાનો હોય ત્યારે સ્ટવમાં કેરોસીન ભર્યા બાદ એક કલાક પછી સળગાવવો.

૩) કાણાવાળું સીલીન્ડર તથા વાસણ રાખવાની પ્લેટ સમકેન્દ્રીત રહે એવી રીતે ફીટ કરો.

૪) વાટનાં રેગ્યુલેટર વડે વાટને ઉંચી કરો આપેલ સ્પેશીયલ કાકડાને કેરોસીનમાં ઝબોળો અને તેને ચેટાવો. કાંણાવાળા સીલીન્ડર વચ્ચે રીંગ આકારની જગ્યા પાસેથી વાટને કાકડા વડે સળગાવો આકૃતિ નં. ૧ મુજબ. કાંણાવાળુ સીલીન્ડર સ્ટવ સળગાવતી વખતે બહાર કાઢવાની જરૂર નથી. એક જ મીનીટમાંજ બલ્યુ જયોત નીકળતી દેખાશે. બલ્યુ જ્યોત રહે તે રીતે રેગ્યુલેટર એડજેસ્ટ કરો.
હવે 'અશોક' આપની રસોઇ કરવા તૈયાર.

"વાટ ગોઠવવાની રીત"

૧) વાટને ૧ કલાક કેરોસીનમાં બોળી રાખો.
૨) વાટને બરોબર વચ્ચેથી પીન પર લટકાવો આકૃતિ નં. ૨માં બતાવ્યા મુજબ.

૩) પીનને બર્નરમાંથી વાટ સાથે પસાર કરો અને ખેંચો આકૃતિ નં. ૩ પ્રમાણે.

૪) વાટને ઉપરનાં ભાગે એક સરખી કરવા તેનાં ખુલ્લા છેડે કાપો. આકૃતિ નં ૪ પ્રમાણે.

૫) વાટ રેગ્યુલેટર તદન નીચે રાખી, પીન કાઢી લઈ વાટને તેનાં ખુલ્લા છેડા બર્નરની ટોચે પહોંચે ત્યાં સુધી ખેંચો. આકૃતિ નં. ૫ પ્રમાણે.

૬) દરેક વીક ટ્યુબમાં (વાટની ભુંગળીમાં) વાટ નાખવી. કોઈપણ ટ્યુબમાં વાટ રહી ન જાય તેની ખાત્રી કરી લેવી.

"અશોક સ્ટવની જાળવણી કરવાની રીત"

દર અઠવાડીયે જ્યોતને તપાસો. જો એકસરખી જ્યોત ન હોય તો ઉપર જણાવ્યા મુજબ વાટને વ્યવસ્થિત ગોઠવો. સામાન્યરીતે પંદર દિવસમાં એક વખત નીચે જણાવ્યા મુજબ વાટને વ્યવસ્થિત કરવી સલાહ ભર્યું છે.

૧) વાસણ મુકવાની પ્લેઈટ, અંદરના તથા બહારના કાંણાવાળા સીલીન્ડરો અને બર્નર અલગ કરો.

૨) વાટને એક ઇંચ જેટલી બહાર નીકળે તેમ ખેંચો. બળી ગયેલ વાટ કાપી નાંખો અને વાટને આકૃતિ નં. ૪ અને ૫ માં બતાવ્યા પ્રમાણે ફરી વ્યવસ્થિત કરો.

૩) ટાંકીને મહીને એકવાર અંદરથી જરૂર સાફ કરો.

૪) ભેળસેળ વાળું કેરોસીન અને ઉભરાયેલ ખાદ્યપદાર્થોને કારણે કેરોસીનની વાટ મારફત ઉપર ચઢવાની પ્રક્રિયા અવરોધાય છે જેને કારણે જ્યોત ઓછી પ્રગટે છે અને સ્ટવની કાર્યક્ષમતા ઘટે છે. તેવા સંજોગોમાં વાટને તુરતજ ઉપર જણાવ્યા પ્રમાણે કાપી નાખવી સલાહ ભર્યું છે. ખાત્રી કરી લેશો કે સ્ટવમાં વપરાતું કેરોસીન ભેળસેળ રહીત છે.

"અશોક સ્ટવ" પાસે અવિરત કામગીરી મેળવવા ઉપયોગી સુચનો:

૧) સ્ટવમાં કેરોસીન નોજ ઉપયોગ કરવો. કેરોસીન સિવાયનું બીજું કોઈપણ ઇંધણ હાનીકારક છે.
૨) સ્ટવમાં હમેશા પૂરતું કેરોસીન ભરવું.
૩) સ્ટવમાં કોઈપણ એકાદ વાટ ન હોય તો તેનો ઉપયોગ કરશો નહિં.
૪) સ્ટવ નો ઉપયોગ બારીમાંથી સીધા ફેંકાતા પવન ઉપર અથવા પંખા નજીક કરવો હિતાવહ નથી.
૫) સ્ટવને સળગતો એક જગ્યાએથી બીજી જગ્યાએ ખસેડવો નહીં.
૬) સ્ટવ સળગતો હોય ત્યારે કોઈ પણ સંજોગોમાં કેરોસીન પુરવું નહીં. કેરોસીન ભરવા માટે ખાસ દર્શાવેલ જગ્યાએથીજ ભરવાનો આગ્રહ રાખવો. નવા નૂસ્ખા અજમાવશો નહિં.
૭) સળગતી દિવાસળી બર્નર પર પડતી મુકવી નહીં.
૮) નાના વાસણ માટે નાના વાસણ મુકવાની ખાસ પ્લેઈટનો ઉપયોગ કરો. કાંણાવાળા સીલીન્ડરને વાસણ અડે નહીં તે ખાસ ધ્યાન રાખવું.
૯) કાણાવાળું સીલીન્ડર અને વાસણ મૂકવાની પ્લેઈટ સ્ટવ સળગાવતા પહેલાં સમકેન્દ્રીત હોવા જરૂરી છે.
૧૦) નાની ગોળાઇવાળા વાસણનાં ઉપયોગ વખતે તથા પ્રેશર કુકરમાંથી વરાળ નીકળે ત્યારે 'જ્યોત' ઓછી કરવી સલાહ ભર્યું છે.
૧૧) વાટ એ અગત્યનો ભાગ છે. માટે 'અશોક બ્રાન્ડ' નીજ વાટ ઉપયોગમાં લેવી.

"સ્ટવ બુઝાવવાની રીત"

વાટનાં રેગ્યુલેટરને છેક સુધી નીચે કરો. ૧૦ સેકન્ડ પછી વાટ ઓલવવાનાં સાધનને કાંણાવાળા સીલીંડર વચ્ચેની રીંગ આકરની જગ્યામાંથી વાટને અડકે ત્યાં સુધી પસાર કરો. તે સાધનને સ્ટવ ફરી સળગાવવો ન હોય ત્યાં સુધી ત્યાંજ રહેવાદો. (આકૃતિ નં. ૬ પ્રમાણે).

અગત્યની નોંધ:

સ્ટવ ઓલવવા માટે બર્નર પર પાણીનો છંટકાવ ક્યારેય પણ કરશો નહી.

LIGHTING 'ASHOK' Stove:

(1) Fill the oil container with kerosene to three fourths of the full capacity.

(2) 'ASHOK' stove, when new should be lit for the first time one hour after filling kerosene in the tank.

(3) Perforated cylinders and the vessel supporting plate fit securely so that they are concentric with each other.

(4) Raise the wicks with the help of wick regulator. Dip the special kindler in kerosene, light it and apply the flame to the wicks through annular gap between the perforated cylinders. Do not remove perforated cylinders every time for lighting the stove.
After about one minute adjust the position of the wick lever for a suitable heat intensify and blue flame condition

HOW TO ADJUST WICKS:

1. Soak the wicks for about an hour in kerosene.

2. Hang a wick at its middle point through a pin as shown in photograph 2

3. Pull the pin through the burner as in photograph 3

4. Cut the wicks at the free end to make the top uniform as shown in photograph 4

5. Remove the pin and pull the wick till its free end & adjust the burner top as shown in photograph 5, when the wick lever is at the lowermost position.

6. Wicks should be replaced in all wick tubes and none of the tubes should be left unoccupied.

Maintenance of 'ASHOK' Stove:

Examine the flame every week. In case the flame appears to be non-uniform, adjust the wicks as described above. Once in a fortnight, in normal conditions of use, it is suggested that the wicks be adjusted as per the following procedure.

(a) Remove the vessel supporting plate, inner & outer perforated cylinders and the burner.

(b) Pull the wicks up one inch & cut the burnt portion. Then adjust as shown in photographs 4 & 5.

(c) Clean the oil container at least once a month.

(d) Dirty kerosene & falling of cooking products reduces the rising of kerosene through wicks which results in shortening of flame and poor efficiency. In case of any milk or food stuff spoiling the wicks, cut off as, explained above. Ensure that the kerosene used in this stove is not adulterated.

Useful hints for trouble free operation from 'Ashok' Stove:

1. The stove shall use kerosene only and the use of fuels other than kerosene is dangerous.

2. The maximum quantity or level of kerosene to be filled in the container for normal use is maintained.

3. The stove shall not be used with any of the wicks missing.

4. The stove shall not be used at a place where there is direct wind draft from windows and fans.

5. Avoid moving of the stove from one place to another in lighted conditions.

6. It is dangerous to pour kerosene in the fuel container while the stove is burning and any short cut or direct method of pouring kerosene into the fuel container should be avoided.

7. Never drop lighted match sticks into burner.

8. Use the supports if required while putting small vessel. Also ensure that it does not touch or rest directly on the perforated cylinder.

9. Before lighting the stove each time, ensure that the perforated cylinders and vessels support plate are concentric and properly secured.

10. Always reduce the flame while using vessels of small diameters and after the pressure cooker starts steaming.

11. Wick is the most important component. **Always use 'Ashok' brand wicks.**

HOW TO EXTINGUISH?

Push the wick lever to its lower most position. After 10 seconds lower the flame extinguisher through the annular space between the perforated cylinders as shown in photograph 6. Keep the extinguisher in place till stove is lit again.

IMPORTANT NOTE:

Do not sprinkle water on the burner for extinguishing the flame.

Ashok (1-7)

ASHOK IRON & STEEL FABRICATORS RAJKOT

Manufactured by:
M/s. Ashok Iron & Steel Fabricators
Rajkot-360 002 (India)

Marketed by:
M/s. Mira Udyog
Rajkot-360 004 (India)

Technical Consultants:
M/s. Ashok Machine Tools
Rajkot-360 004 (India)

Before using 'Ashok Stove' please go through the instructions contained here carefully so as to get a better performance

'Ashok' Stove at Glance:

1. Type: Multi wick non-pressurised kerosene stove

2. Oil Container Capacity: 3 litres (approximately)

3. No. of Wicks: 10 (Ten)

4. Kerosene Consumption Rate (gms/hr): 140—160

5. Useful Heat Output (K. Cals/hr): 940—950

6. Thermal Efficiency: 58 to 60%

'ASHOK' Stove-Special Features.

1. The material construction used in 'Ashok' stove tested and is of robust quality to ensure trouble free service.

2. 'ASHOK' stove if used as per the information and instructions contained herein will give 20/30% saving in kerosene consumption.

3. 'ASHOK' stove has been designed beautifully and perfectly to give high heat output of the same order as achievable in case of gas stove

4. 'ASHOK' stove is also suitable to withstand heavy cooking vessels.

5. 'ASHOK' stove provides beautifully designed wick regulator to provide heat output in a wide range.

6. 'ASHOK' stove means blue flame with effective control and no shoot.

Ashok
(1-7)

7

અન્ય સામગ્રી

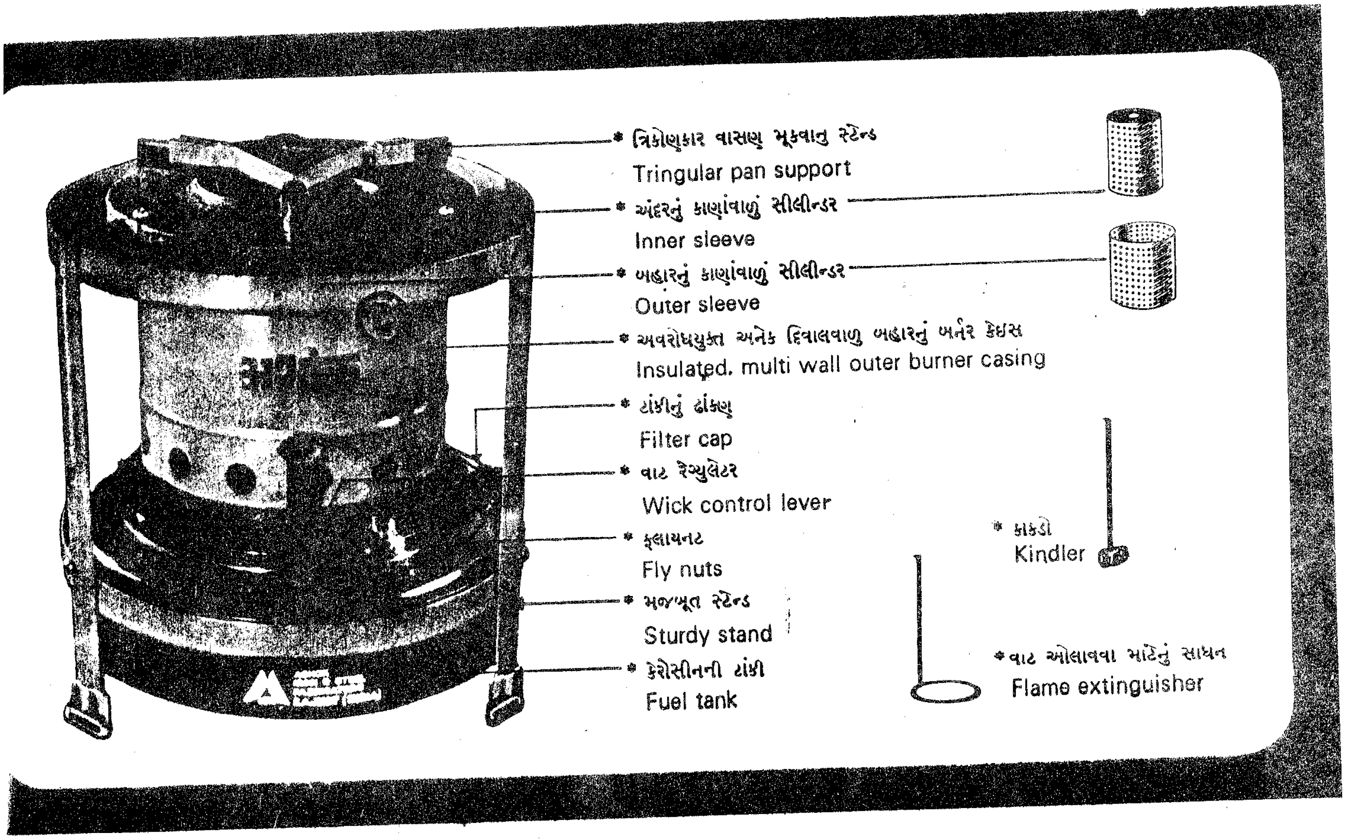
અશોક સ્ટવ સાથે નીચે મુજબની અન્ય સામગ્રીઓ છે તેની કૃપા કરી ખાત્રી કરી લ્યો

૧) વાટ સળગાવવા માટેનો ખાસ કાકડો.
૨) પીન-વાટને વાટના પાઈપમાં નાખવા માટે.
૩) ત્રિકોણ સ્ટેન્ડ-નાના વાસણને સ્ટવ ઉપર બરાબર રાખવા માટે
૪) દસ વાટની વધારાનો સેટ.
૫) વાટ ઓલાવવા માટેનું સાધન.

:cessories:

Please ensure that Ashok wick stove comes with the following accessories:

1. Special kindler (to light wicks)
2. Pin (to insert wicks in wick pipes)
3. Triangular pan support (to support small vessels on your stove)
4. Extra set of 10 wicks
5. Flame extinguisher

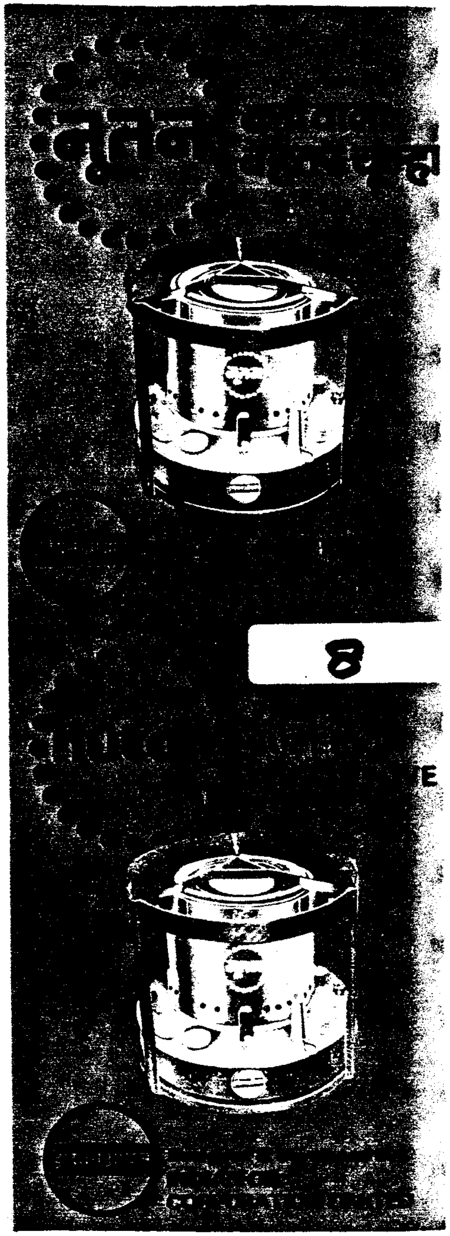


Reg. Design No. 50811/1981
Reg. Design No. 50828/1981

Verified & Checked

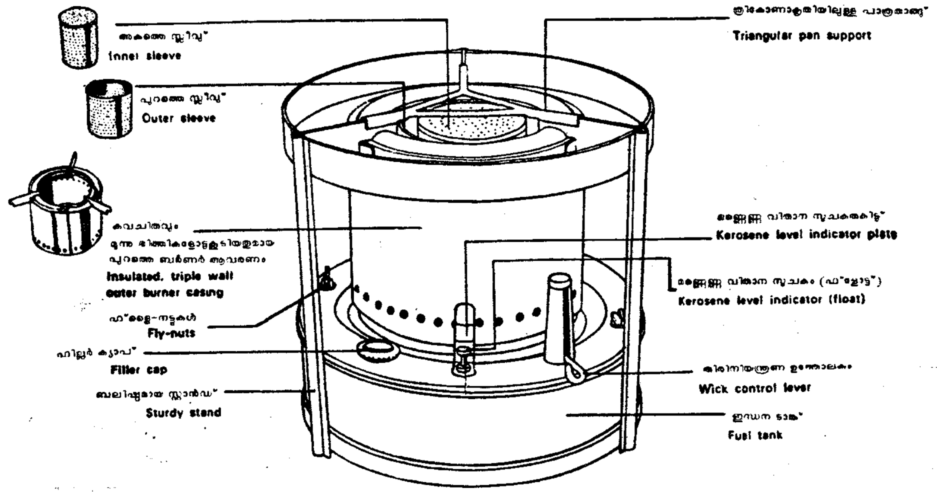
Manufactured by:
Ashok Iron Steel Fabricators
Rajkot 360 002 (India)
Phone: 28215/8443
Gram: "ASHOK STOVE"

Marketed by:
MIRA UDYOG
Mavdi Plot,
Rajkot-360 004 (India)
Phone: 28580/8553
Gram: "ASHOK STOVE"



NUTAN—A BETTER STOVE

After extensive experimentation and research, Indian Oil's Research & Development Centre at Faridabad has designed and developed the new NUTAN Kerosene Wick Stove which **Saves 30% kerosene** on an average, while **giving a thermal efficiency** (effective heat utilisation) **of over 60%** as compared to the 35% to 47% efficiency of most other wick stoves sold in the market. NUTAN also **cooks 25% faster** than these popular brands.



 നൂതന്റെ മുന്തിയ സവിശേഷതകൾ

SALIENT FEATURES OF NUTAN

Specially designed burner assembly consisting of inner and outer sleeves, improves effective heat utilisation, ensures better combustion and minimises soot formation. The unique air pre-heater assembly heats the air before it reaches the wicks for better burning. It also keeps the fuel tank cool.

Insulated, triple wall outer burner casing is specially designed to cut down heat wastage, make for cooler operation. The space between the two inner walls is designed to supply more pre-heated air to ensure maximum combustion. Special insulation between the two outer walls keeps the outer surface of the burner casing cool and cuts down heat losses.

Specially designed flame deflecting ring on top of the outer burner casing effectively concentrates the flame on the vessel to provide more useful heat.

Load bearing assembly: of unique design prevents the outer burner casing from moving out of place...keeps the entire burner assembly in proper concentric position. The sturdy stand is designed specially to accommodate large or medium-size vessels safely—a triangular pan support permits small utensils also to be placed.

Kerosene level indicator (float)—a built in convenience—tells at a glance the level of kerosene in the fuel tank ..helps prolong wick life.

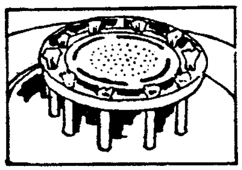
New wick control lever specially designed for easy raising/lowering of wicks...lets you control the intensity of the flame more accurately.

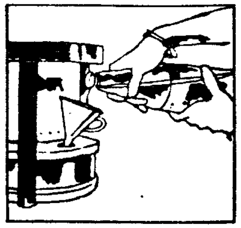
ഉപയോഗിക്കുന്നതിനുള്ള നിർദ്ദേശങ്ങൾ

പ്രാഥമിക കാര്യങ്ങൾ

PRELIMINARIES

Before lighting a new stove, remove the outer burner casing and sleeves. Raise the wick control lever to its maximum level and ensure that all 10 wicks are in position. Clip the wicks with sharp scissors to the level of the outer rim of the wick carrier. Operate the lever a few times to see that it moves smoothly Put back burner sleeves and outer burner casing securely, the arrow (↑) on the outer sleeve pointing up word. Inner and outer sleeves should be concentric — not tilting to any side. This is necessary to keep the space between them and the outer burner casing equal.

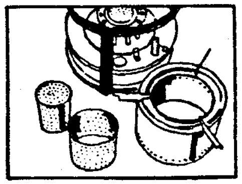


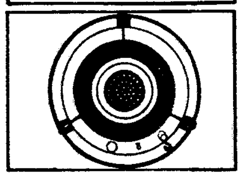


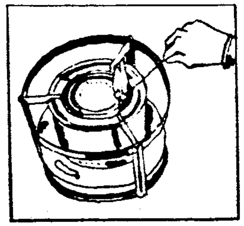
ടാങ്ക് നിറയ്ക്കുന്നതിന്

TO FILL TANK.

Unscrew filler cap, and slowly pour in kerosene by means of a funnel, till the kerosene level indicator rises up to the top edge of the green mark on the indicator plate. Never fill the fuel tank beyond the green mark, to avoid kerosene spilling.







കത്തിക്കുന്നതിന്

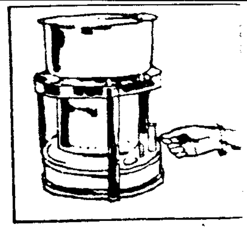
ഒരു പ്രധാന കാര്യം

TO LIGHT UP:

Raise the wick control lever to the top. Dip the special kindler in kerosene, light it, and light the wicks with it.

IMPORTANT

When you light a new stove, wait for the protective paint on the burner sleeves to burn out completely before you start cooking.



തീജ്വാല നിയന്ത്രിക്കുന്നതിന്

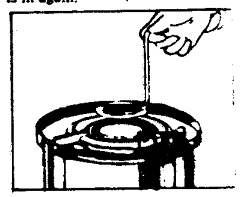
TO REGULATE FLAME:

Place a vessel on the lighted stove Gradually adjust the wicks by means of the wick control lever until a maximum blue flame is obtained – this will give the best result

തീജ്വാല കെടുത്തുന്നതിന്

TO PUT OUT FLAME

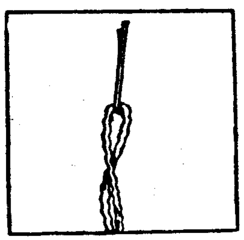
Lower the wick control lever to its lowest level and insert the special flame extinguisher provided as shown in the illustrations Keep the extinguisher in place till stove is lit again.



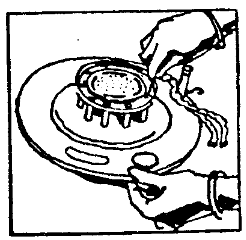
തിരികൾ പകരം വയ്ക്കുന്നതിന്

TO REPLACE WICKS

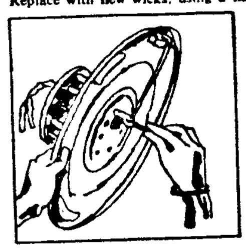
Unscrew fly-nuts, remove tank cover carefully, and pull out used wicks Replace with new wicks, using a hair pin, as follows:



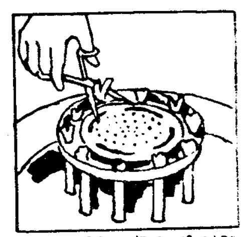
Put ends of wick together and pass pin through loop.



Insert pin into wick pipe from the top.



Pull pin out at the other end of pipe, bringing the wick with it.



Trim the tops of the wicks, so that they are level with outer rim of wick carrier.

TO GET OPTIMUM PERFORMANCE FROM YOUR NUTAN STOVE

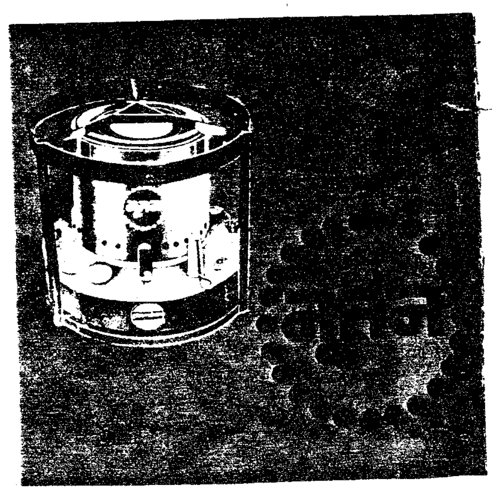
DOs

- Check that all the components of the stove are in proper position, and that the sleeves and outer burner casing are correctly and securely placed with uniform spacing in-between.
- Use a vessel larger than 15 cms. (dia.) for better heat utilisation. The larger the vessel, the better the result.
- Always use NUTAN wicks for best results.
- For maximum fuel economy, always adjust the wicks to the correct height with a vessel placed on the stove. This should give a blue, and not a yellow flame.
- Always use the special kindler provided to light the stove.

  Check kerosene level before lighting the stove. Make sure the kerosene level is always above the red mark and below the yellow mark. This helps to improve the wick life.
- Use the stove in a sheltered, draught-free place.

DON'Ts

- **Do not remove the fuel tank from its original position in the stand.**
- **Do not light the stove without first making sure that all the ten wicks are in position in their respective pipes and are uniform in height.**
- **Never pour kerosene into the fuel tank when the stove is burning.**
- **Never blow out the flame with the wicks in raised position.**
- **Don't carry a lighted stove from one place to another, as a matter of personal safety.**
- **Never keep a burning stove close to a gas cylinder.**
- **Don't handle the stove in a tilted position; otherwise kerosene will spill.**



വിവരങ്ങൾ

a)	തിരികളുടെ എണ്ണം	: 10
b)	ഒഴിഞ്ഞ സ്റ്റൗവിന്റെ ഭാരം	: 2.60 കിലോഗ്രാം
c)	ഉയരം	: 23.5 സെ.മീ
d)	വ്യാസം	: 26.5 സെ.മീ
e)	ഇന്ധന ടാങ്കിന്റെ വ്യാപ്തം	: 2.0 ലിറ്റർ
f)	മണ്ണെണ്ണയുടെ ഉപയോഗനിരക്ക്	: മണിക്കൂറിൽ 130 ഗ്രാം
g)	താപക്ഷമത	: 60%
h)	പ്രയോജനകരമായ ചൂടിന്റെ ഉൽപാദനം	: മണിക്കൂറിൽ 825കി. കലോറി

SPECIFICATIONS

a)	Number of wicks	- 10
b)	Weight of empty stove	- 2.60kg.
c)	Height	- 23.5 cm
d)	Diameter	- 26.5 cm
e)	Fuel Tank Capacity	- 2.0 litres
f)	Kerosene Consumption Rate	- 130 gm/hr.
g)	Thermal Efficiency	- 60%
h)	Useful Heat Output	- 825 kcal/hr

MAINTENANCE—HINTS TO KEEP YOUR NUTAN STOVE IN WORKING TRIM

To ensure that your NUTAN stove continues to give improved performance year after year, we recommend the following:

- Once a fortnight, adjust the height of the wicks to the level of the outer rim of the wick carrier and trim the tops slightly.
- Avoid spilling food on the stove. Clogged sleeves and wet wicks will hamper proper burning of the stove.
- Clean sleeve holes and wick carrier periodically.

If the flame is not uniform or appears yellow from one side, check the following

(a) Wicks may require trimming;
(b) Holes of the sleeves may be blocked;
(c) Inner or outer sleeve may be inclined.

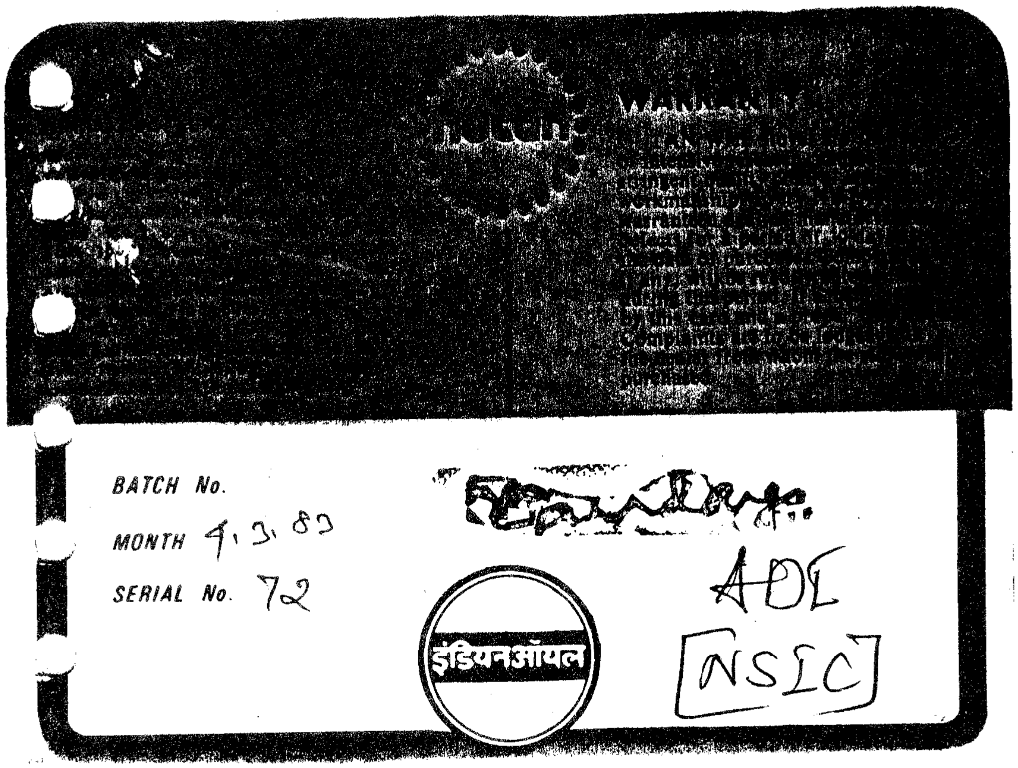
Clean the Kerosene tank at least once a month and remove sludge if any.

SPARE PARTS

സ്പെയർപാർട്ടുകൾ

1. Outer Sleeve
2. Inner Sleeve
3. Fuel Tank Cover (with Fixed Components)
4. Filler Cap
5. Fly Nuts with Washers
6. Set of Wicks
7. Kerosene Level Indicator
8. Triangular Pan Support
9. Kindler
10. Flame Extinguisher
11. Kerosene Tank
12. Stand

Nutan
(2-8)



BATCH No.

MONTH 4.3.83

SERIAL No. 72

इंडियनऑयल

ADE

NSIC

അനുബന്ധ ഉപകരണങ്ങൾ

നിങ്ങളുടെ നൂതൻ വിക്ക് സ്റ്റൗവിനോടൊപ്പം താഴെ പറയുന്ന അനുബന്ധഉപകരണങ്ങൾ ഉണ്ടോയെന്ന് ദയവായി പരിശോധിച്ചുനോക്കുക :

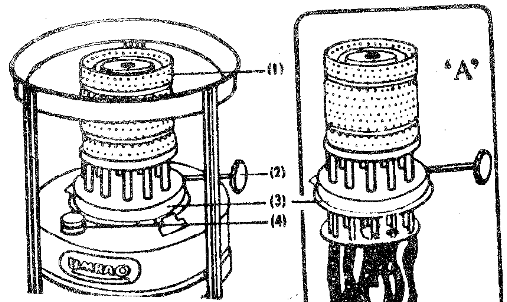
1. പ്രത്യേക തീകൊളുത്തൽ ഉപകരണ (തിരികൾ കത്തിക്കുന്നതിന്)
2. പിൻ (തിരികൾ തിരികുഴലുകളിൽ കടത്തുന്നതിന്)
3. ത്രികോണാകൃതിയിലുള്ള പാത്ര താങ്ങ് (നിങ്ങളുടെ സ്റ്റൗവിൽ ചെറിയ പാ്രങ്ങൾ താങ്ങിനിറുത്തുന്നതിന്)
4. 10 തിരികളുടെ ഒരു പ്രത്യേക ഗണം
5. ... കെടുത്തൽ ഉപകരണം.

8

Accessories:

Please check that your NUTAN Wick Stove comes with the following accessories:

1. Special Kindler (to light wicks)
2. Pin (to insert wicks in wick pipes)
3. Triangular Pan Support (to support small vessels on your stove)
4. Extra set of 10 wicks.
5. Flame Extinguisher.



9

● କିରୋସିନ ଭରିବା ପାଇଁ କ୍ୟାପ ନଂ. ୪ କୁ ଖୋଲନ୍ତୁ । ● ଉପଯୁକ୍ତ ଅଗ୍ନିଶିଖା (ନୀଳ) ପାଇବା ପାଇଁ ବତୀଗୁଡ଼ିକର ଉଚ୍ଚତା ସମାନ ରଖନ୍ତୁ । ● ବତୀଗୁଡ଼ିକ ଜଳାଇବା ପାଇଁ ବର୍ନର ନଂ. 1 କାଢ଼ି ଦିଅନ୍ତୁ । ● ଉତ୍ତାପ ବଢ଼ାଇବା ପାଇଁ କିମ୍ବା କମାଇବା ପାଇଁ ନବ୍ ନଂ. 2 କୁ ବୁଲାନ୍ତୁ । ● ବତୀ ବଦଳାଇବା ପାଇଁ ନଂ. 3 କୁ ବୁଲାଇ ଭାଗ 'A' କୁ ଟ୍ୟାଙ୍କରୁ ଅଲଗା କରି ଦିଅନ୍ତୁ । ବତୀର ଗୋଟିଏ ଭାଗ ସୂତାରେ ବାନ୍ଧି ଗୋଟିଏ ଛୁଞ୍ଚିରେ ତାକୁ ଉପରକୁ ଟାଣନ୍ତୁ ।

● కిరసనాయిల్ పోసేందుకు మూత నం. 4 తెరవండి ● సరియైన (నీలి రంగు) మంట వచ్చేందుకు వత్తులను సరిసమానమైన ఎత్తులో ఉంచేటట్లు చూడండి ● వత్తులను వెలిగించేందుకు, బర్నర్ నం. 1 తొలగించండి ● వేడిమి ఎక్కువ చేసేందుకుగాని తగ్గించేందుకుగాని, నాబ్ నం 2 త్రిప్పండి ● వత్తులను తిరిగి ఎక్కించేందుకు, నం 3 త్రిప్పి 'A' భాగమును వేరుచేయండి వత్తి యొక్క ఒక కొసను దారము కట్టి, సూది సహాయంతో పైకిలాగండి.

● কেরোসিন ভরার জন্যে 4 নং ক্যাপ খুলুন। ● সঠিক (নীল) আঁচের জন্যে সলতে সবজায়গায় সমান উঁচু রাখুন। ● সলতে জ্বালাবার জন্য 1 নং বার্নার সরান। ● আঁচ বে কম করতে হলে 2 নং গোল হাতলটা ঘোরান। ● সলতে বদলাবার জন্য 3 নং ঘুরিয়ে ট্যাঙ্ক থেকে 'A' অংশটি খুলে নিন। সলতের এক মুখে সুতো বেঁধে ছুঁচ দিয়ে সেটা ওপরে তুলুন।

● മണ്ണെണ്ണ നിറയ്ക്കാൻ ക്യാപ് നമ്പർ 4 തുറക്കുക ● ശരിയായ (നീല) ജ്വാല കിട്ടാൻ, നാടകളെല്ലാം ഒരേ പൊക്കത്തിൽ നിറുത്തുക ● നാടകൾ കത്തിക്കാൻ, ബർണർ നമ്പർ 1 എടുത്തു മാറ്റുക ● ചൂട് കൂട്ടുന്നതിനോ, കുറയ്ക്കുന്നതിനോ നോബ് നമ്പർ 2 തിരിക്കുക ● നാടകൾ മാറ്റി ഇടുവാൻ, നമ്പർ 3 തിരിച്ച് 'A' ഭാഗം ടാങ്കിൽ നിന്നു വേർപെടുത്തിയെടുക്കുക. നാടയുടെ ഒറ്റത്ത് നൂല് പിടിപ്പിച്ച് ഒരു സൂചിയുടെ സഹായത്തോടുകൂടി മേൽപോട്ട് വലിക്കുക.

● கிரோசின் நிரப்புவதற்கு மூடி ந. 4-ஐத் திறக்கவும். ● சரியான (நீல) தீக்கொழுந்தைப் பெற, திரிகளை சம உயரத்தில் வைத்திருக்கவும். ● திரிகளைப் பற்றவைக்க பர்னர் ந 1ஐ அகற்றவும். ● சூட்டைக் குறைப்பதற்கோ அதிகமாக்குவதற்கோ, திருகு ந. 2-ஐத் திருப்பவும். ● திரிகளை மாற்ற, 3-ஐத் திருப்பி 'A' என்ற பாகத்தை டாங்கிலிருந்து பிரிக்கவும். திரியின் ஒரு முனையை நூலில் கட்டி, ஊசியின் உதவியினால் அதை மேலெழுக்கவும்.

● To fill Kerosene, open Cap No. 4 ● To get proper (blue) flame, keep wicks in even height ● To light the wicks remove burner No. 1 ● To increase or decrease heat, turn knob No. 2 ● To replace wicks, separate part 'A' from the tank by turning No. 3. Tie one end of wick with thread and pull it up with the help of a needle.

● لملا النفط، إفتح غطاء رقم 4 ● للحصول على الشعلة الزرقاء المناسبة، اجعل الفتيلات على قدر واحد من الارتفاع سوية ● لإشعال الفتيلات، اخلع النافخة رقم 1 ● لاستكثار او لتقليل الحرارة، حوّل المقبض رقم 2 ● لتبديل الفتيلات، اخلع الجزء "A" من الحوض بواسطة تحويل رقم 3. اربط طرف من الفتيلة مع الخيط وارفعه الى الفوق بمساعدة إبرة.

● مٹی کا تیل بھرنے کے لئے، ڈھکن نمبر 4 کھولیے۔ ● مناسب قسم کے (نیلے) شعلوں کے لئے بتیوں کی اونچائی یکساں رکھیے۔ ● بتیوں کو جلانے کے لئے، برنر نمبر 1 کو نکال لیجئے۔ ● آنچ کو زیادہ یا کم کرنے کے لئے، موٹھ نمبر 2 کو گھمائیے۔ ● نئی بتیاں ڈالنی ہوں تو نمبر 3 کو گھما کر ٹنکی سے حصہ 'A' کو الگ کیجئے۔ بتی کے ایک سرے کو دھاگے سے باندھئے اور سوئی کے ذریعے اسے اوپر کھینچ لیجئے۔

● मिट्टीका तेल भरने के लिए ढक्कन (नं. 4) खोलीए। ● उत्तम (नीली) ज्योत पानेके लीए सबही बत्ती समान उचाइ पर रखे ● बत्ती जलानेके लीए बर्नर (नं. 1) उठाइएं। ● गरमी कम या ज्यादा करनेके लीए गोल चाबी (नं. 2) फीराइए। ● नई बत्ती बदलनेके लीए (नं. 3) फीराकर भाग 'A' टंककीसे अलग करे और बत्तीका एक मुह धागेसे बांधकर सुईकी सहायतासे उपरकी ओर खींचीए।

● કેરોસીન ભરવા માટે ઢાંકણું (નં. 4) ખોલો. ● સારી (ભૂરી) જ્વાળા માટે બધી વાટો સરખી ઉંચાઈએ રાખવી. ● વાટો સળગાવવા બર્નર (નં. 1) ઉઠાવવું. ● ગરમી વધારવા કે ઘટાડવા ગોલ ચાવી (નં. 2) ફેરવવું. ● નવી વાટ બદલવા (નં. 3) ફેરવી ભાગ 'A' ટાંકીથી છુટો કરો. ● વાટના એક છેડે દોરો બાંધી સોયાની મદદથી ઉપર ખેંચો.

● रॉकेल भरण्यासाठी झाकण (क्र. 4) उघडा. ● उत्तम (निळी) ज्योत येण्यासाठी वाती समांतर उंचीवर ठेवा. ● वाती पेटविण्यासाठी बर्नर (क्र. 1) उचला. ● आच कमीजास्त करण्यासाठी गोल चावी (क्र. 2) फिरवा. ● नवीन वाती बसविण्यासाठी (क्र. 3) फिरवून भाग 'A' टाकीपासून वेगळा करा. वातीच्या एका टोकाला दोर बांधून सुईच्या साहाय्याने वर खेचा.

● ಸೀಮೆ ಎಣ್ಣೆಯನ್ನು ತುಂಬಿಸಲು ಕ್ಯಾಪ್ ನಂ. 4ನ್ನು ತೆರೆಯಿರಿ. ● ಸರಿಯಾದ (ನೀಲಿ) ಜ್ವಾಲೆಯನ್ನು ಪಡೆಯಲು ಬತ್ತಿಗಳನ್ನು ಸಮಾನ ಎತ್ತರದಲ್ಲಿಡಿ. ● ಬತ್ತಿಗಳನ್ನು ಉರಿಸಲು ಬರ್ನರ್ ನಂ. 1ನ್ನು ತೆಗೆಯಿರಿ. ● ಉಷ್ಣತೆಯನ್ನು ಹೆಚ್ಚಿಸಲು ಅಥವಾ ಕಡಿಮೆ ಮಾಡಲು ನಾಬ್ ನಂ. 2ನ್ನು ತಿರುಗಿಸಿ. ● ಹೊಸ ಬತ್ತಿಗಳನ್ನು ಹಾಕಲು ನಂ. 3ನ್ನು ತಿರುಗಿಸಿ ಭಾಗ 'A'ಯನ್ನು ಟ್ಯಾಂಕ್‌ನಿಂದ ಬೇರ್ಪಡಿಸಿರಿ. ಬತ್ತಿಯ ಒಂದು ತುದಿಯನ್ನು ನೂಲಿನಿಂದ ಕಟ್ಟಿರಿ ಮತ್ತು ಅದನ್ನು ಒಂದು ಸೂಜಿಯ ಸಹಾಯದಿಂದ ಮೇಲಕ್ಕೆಳೆಯಿರಿ.

Warning

Don't Fill The Oil More Than 3/4 of The Tank.

सावधान

तेल की टैंकी को 3/4 भाग से ज़

9

ਸਾਵਧਾਨ

ਤੇਲ ਦੀ ਟੈਂਕੀ ਨੂੰ *3/4* ਹਿੱਸੇ ਤੋਂ ਵੱਧ ਨਾ ਭਰੋ

Technical Engineer

Ogale
13
PRABHAKAR

SAFETY STOVE

NO PIN ★ NO PUMP
NO SMOKE ★ NO NOISE

Made by

Bhandari Porwal Engg. Co. Pvt Ltd.,
Ogalevadi-415 105
(Dist. Satara)

PRABHAKAR
SAFETY STOVE

FOR LIGHTING THE STOVE

Keep the Stove on a Level Surface and open the oil regulator. Remove the burner. Light the oil-soaked wick at two or three places. Place the burner within the guide over the burning wick.

FOR EXTINGUISHING THE STOVE

Close the oil-regulator a couple of minutes before you want to stop and allow the flame to die slowly. Do not overfeed the wick with oil. As the wick is made of asbestos it does not itself burn out. A wick may be changed once in 4 to 6 months if it is rendered useless due to the soot gathered.

FOR CLEANING

Clean the stove once a week

Take out the oil-regulator completely and drain out all the oil from the tube from the regulator end. Take out the asbestos wick. Insert in the cleaning rod through the regulator end of the oil tube and clean throughly the passage as also the hole that feads oil to the wick. If the wick gets soaked due to overflow from the utensil or gets clogged by soot, that wick should be taken out and cleansed. Clean also the burner i. e. both the perforated cylinders. Such cleaning is essential for proper working of the stove.

IDEAL STOVE

Operating Instructions

Note : keep the next items for good efficient & safe use

1) Use the kerosene for fuel surely.
2) Keep out of harm's way fuel from fire.
3) As refueling and moving, put out the flame.
4) Don't slop oil, if slopped, wipe up slops with dry duster.
5) Forbid the use of stove by the inflammables and a danger area, Specially, Don't hang on stove a dishcloth or a wet towel.
6) Forbid the Ues of stove around a gateway or a passageway.
7) Give a glass wick cleaning once a month.
8) Forbid the use of stove on the stope way or windy place.

Efficient Table

Tittle	Heat Vatue	Capacity of tank	Carton D. mensions m/m
IKS-160	1300 Kcal/hr	1.6 ℓ	255X255X255(h)
Type	fuel cousumption	thermal efficient	Continuation Time
upward & Down-ward Type	0.18 ℓ/hr	55 %	9 hr

A major cause for defects & Treatment

Following table shows the cause for simple defect and easy treatment, with this table, customers can use this stove for a long time with good efficient and safety state at all time.

DEFECTS	CAUSE	TREATMENT
Hard Ignition	1) Wick hold water 2) Wick don't go up sufficiently 3) Lack of oil or insufficient 4) Carbides settled on wick 5) Water be mixed in oil	1) Drying or changing wick. 2) Adjust the wick. 3) Supply oil. 4) Burning for cleaning without oil 5) After cleaning of oil tank, supply oil again.
Bad Smelling	1) Wick go up too muck 2) Burner is not stable 3) Lack of oil or insufficient 4) Carbides settled on wick 5) Oil is bad.	1) Adjust the wick. 2) Change the place or keep balance 3) Supply oil 4) Burning for cleaning without oil 5) Change the oil of good quality
Burning with smoke	1) Wick go up too much 2) Burner is not stable. 3) Oil is bad	1) Adjust the wick. 2) Change the place or keep balanec 3) Change the oil of good quality
Burning with devouring flames	1) Wick hold water 2) Wick go up too much 3) Burner is not stable 4) Height of wick is not uniform 5) Oil is bad	1) Drying or Changing wich 2) Adjust the wick 3) Change the place or keep balance 4) Cut the wick uniformly 5) Change the oil of good quality
Make a noise	1) Water mixed in oil	1) After cleaning of oil tank, supply oil again
Burning with devouring flames in one spot.	1) Height of wick is not uniform 2) Burner is not stable.	1) Cut the wick uniformly 2) Change the place or keep balance

NOTICE

The "LARK" Brand Kerosene Stove Art. No.T741 was handled by Tientsin Branch in the past, and from January 1981 on, this product becomes the Export Commodity of Hebei Branch. The "LARK" Brand is to be changed into "FLOWERET", with Art. No. HS811.

As you know, the "FLOWERET" Kerosene Stove HS811 (former "LARK" Brand Art. No. T741) is of high quality, in nice shape, with durable usage and long history and is also easily handled. It has received a good market in the world, comments as well as orders are welcome.

China National Light Industrial Products
Import & Export Corporation
HEBEI BRANCH

中华人民共和国制造
MADE IN THE PEOPLE'S REPUBLIC OF CHINA

"LARK" ECONOMY KEROSENE COOKING STOVE

1) SPECIAL FEATURES:

"LARK" Economy Kerosene Cooking Stove is made of thin steel plate, well enamelled and varnished.

Nice-looking, elegant, economical, handy and convenient, it is noted for low oil consumption, giving strong flames and making little smoke/odour; it is well suitable for all household cooking purposes as well as for travelling use.

2) DIRECTIONS FOR USE:

1. Unscrew the oil tank's lid and pour in an adequate volume of kerosene.
2. Place the chimneys and the innermost hood flat and closely. Turn the regulator to raise the wicks to the burner's level. Very soon the flames will come up themselves, bluish flames most preferred.
3. The flames can be adjusted at wish. After a left-turn of the regulator, the flames will self extinguish.

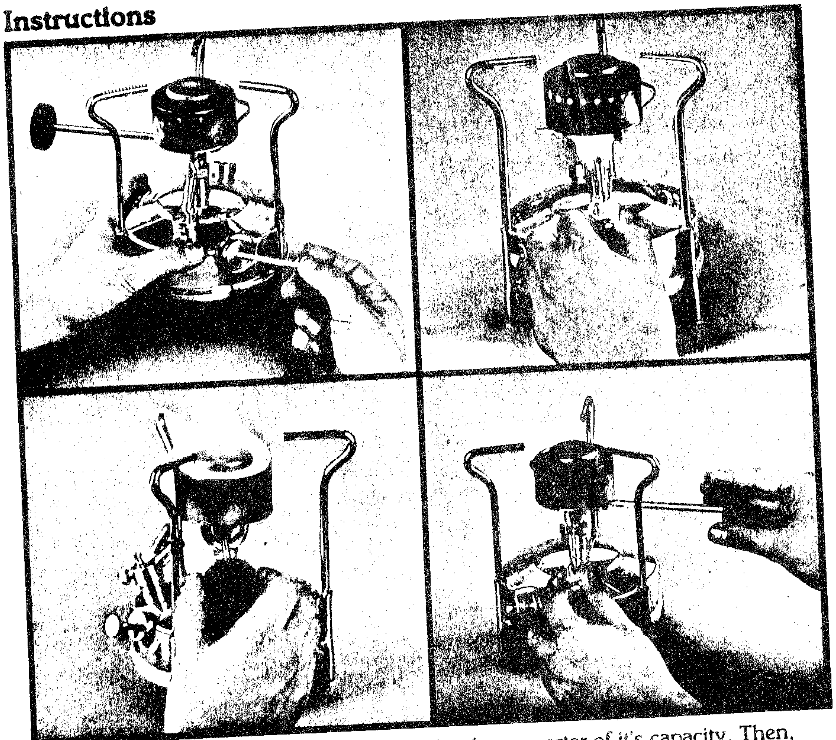
3) PROTECTION:

1. Use only kerosene, but never gasoline.
2. Never try to blow off the fire with your mouth.
3. Always keep an adequate volume of kerosene in the tank. Insufficient oil in store would weaken the flames and char the wicks and make the next lighting difficult.
4. When cooking, let no water/dirt overflow to touch the chimneys/innermost hood/burner because, otherwise, heavy smoke/odour would appear and the flames may even become extinguished and the wicks, charred—all to cause effect affecting the life of the Stove.
5. In order to ensure smooth operation, always keep the Stove clean by clearing off the dirt from the chimneys/innermost hood/burner. **Careful protection is always recommended.**

四、各型油炉规格性能表
Specification List of various Models

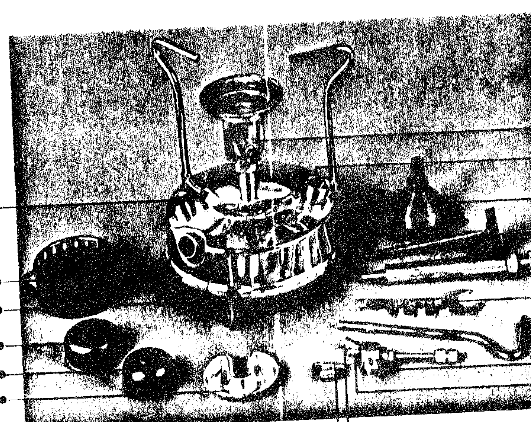
型号 Model No.	容油量 (公斤) (Kg.) Kerosene Capacity	火焰高度 (公厘) (mm) Flame Height	火焰温度 (°C) Degree of Flame Heat (°C)	每小时耗油量 (公斤) Kerosene Consumption Per Hour (Kg.)	室温20°（煮沸4公斤水需用时间 (分) Time needed to boil 4-Kgs, of Water in Room at 20°C (minute)	油炉外径尺寸 (公分) Outside Dimension of Stove (cm)	每纸箱装数量 (打) Quantity Per Carton (Doz.)	每纸箱重量 (公斤) Weight per Carton (Kgs.) 毛重 Gross	每纸箱重量 (公斤) Weight per Carton (Kgs.) 净重 net	每箱体积 (公分) Measurement
T733	1.25	280	780-860	0.15	22	23×23×23.7	1	30	24	72×48×51
T734	1.25	280	780-860	0.15	22	23×23×24	1	30	24	72×48×51

Instructions

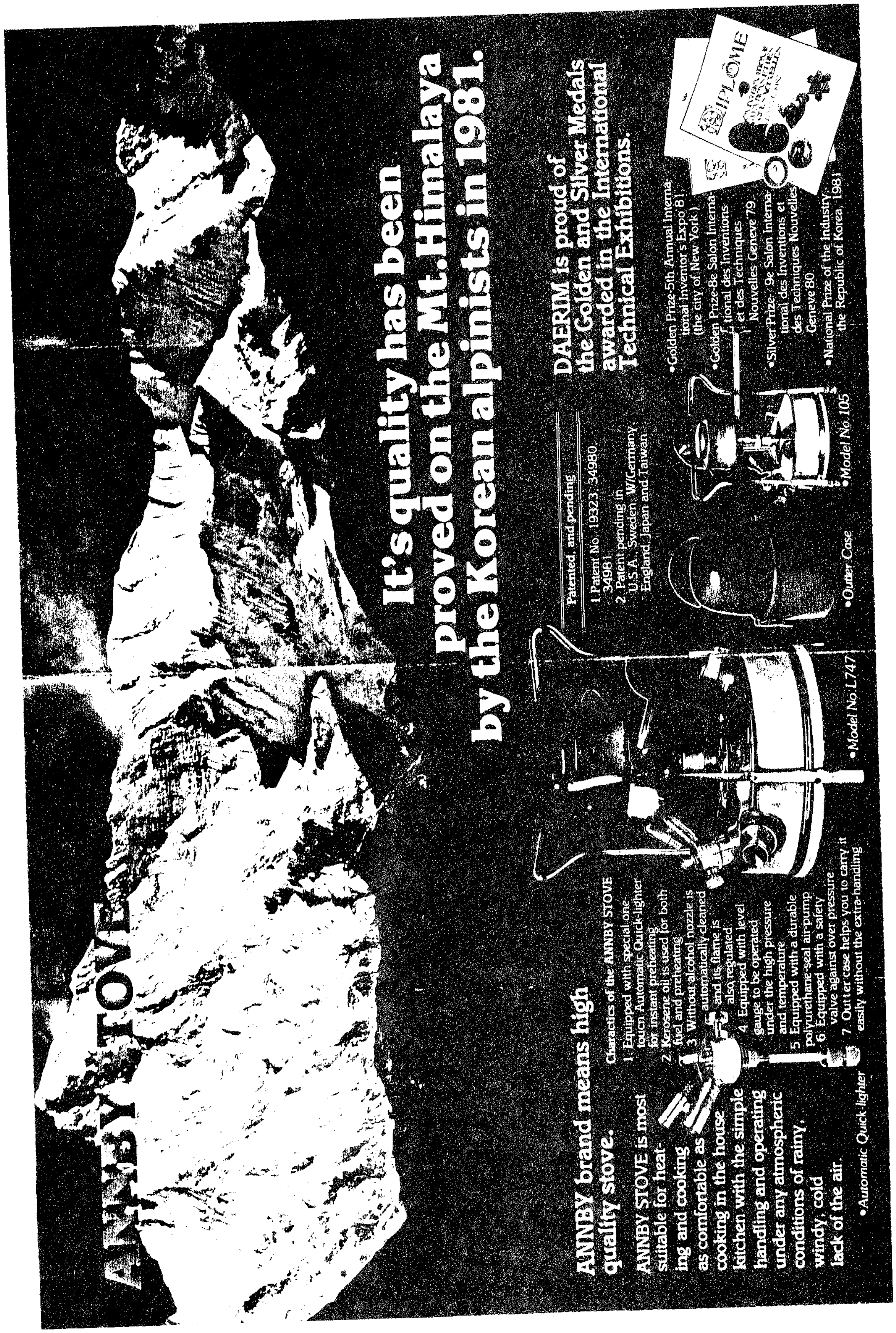


- Fill tank with kerosene oil or gasoline by three-quarter of it's capacity. Then, close the regulating valve and quick-lighter valve by turning clockwise.
- Pump it continously until the container is filled with full of the air. (20-30 times)
- Open the valve of quick-lighter and ignite and pump it continously for the blue-flame (when the flame is irregular, please remove the edge of the lighter forwards)

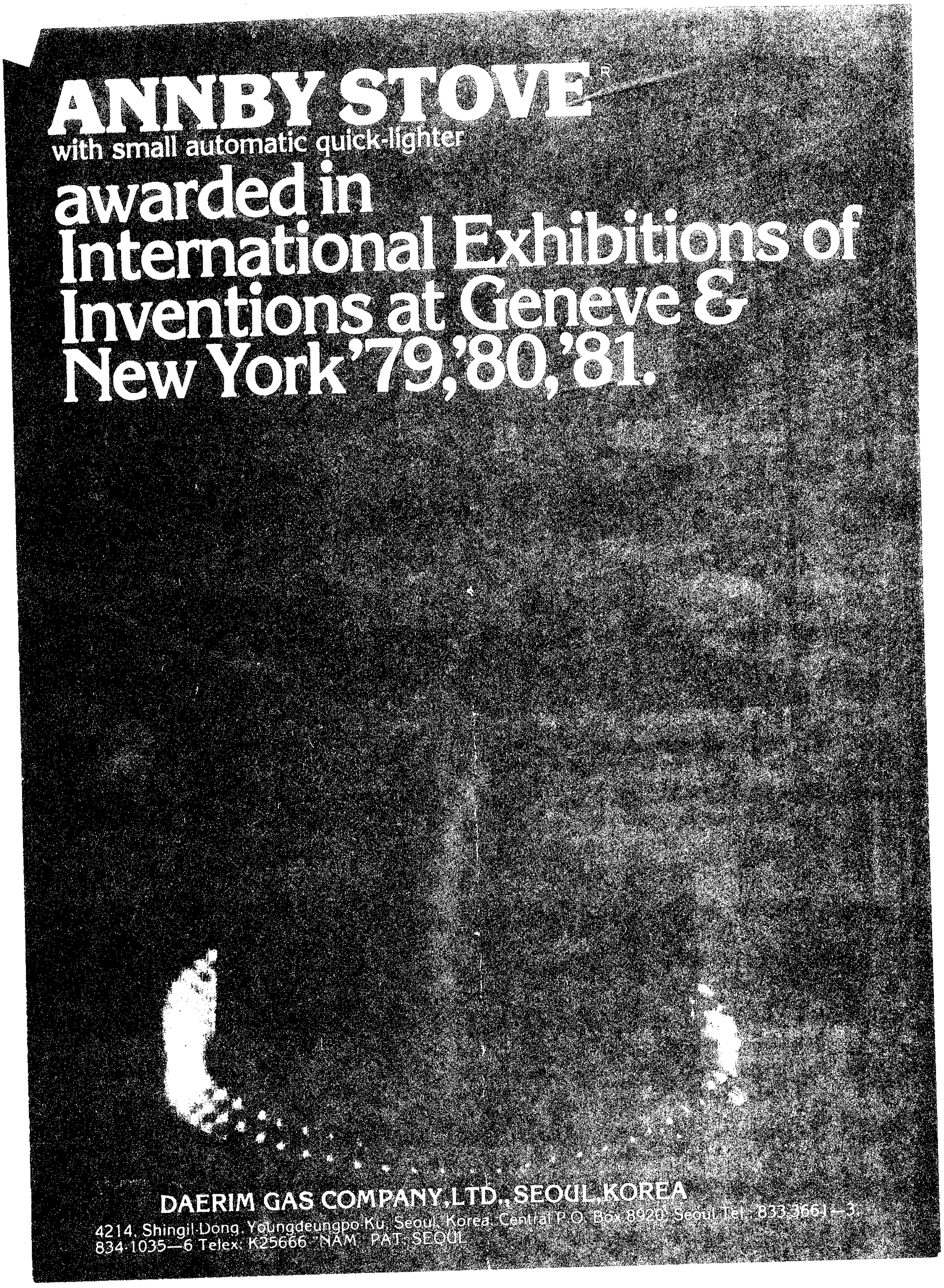
Parts



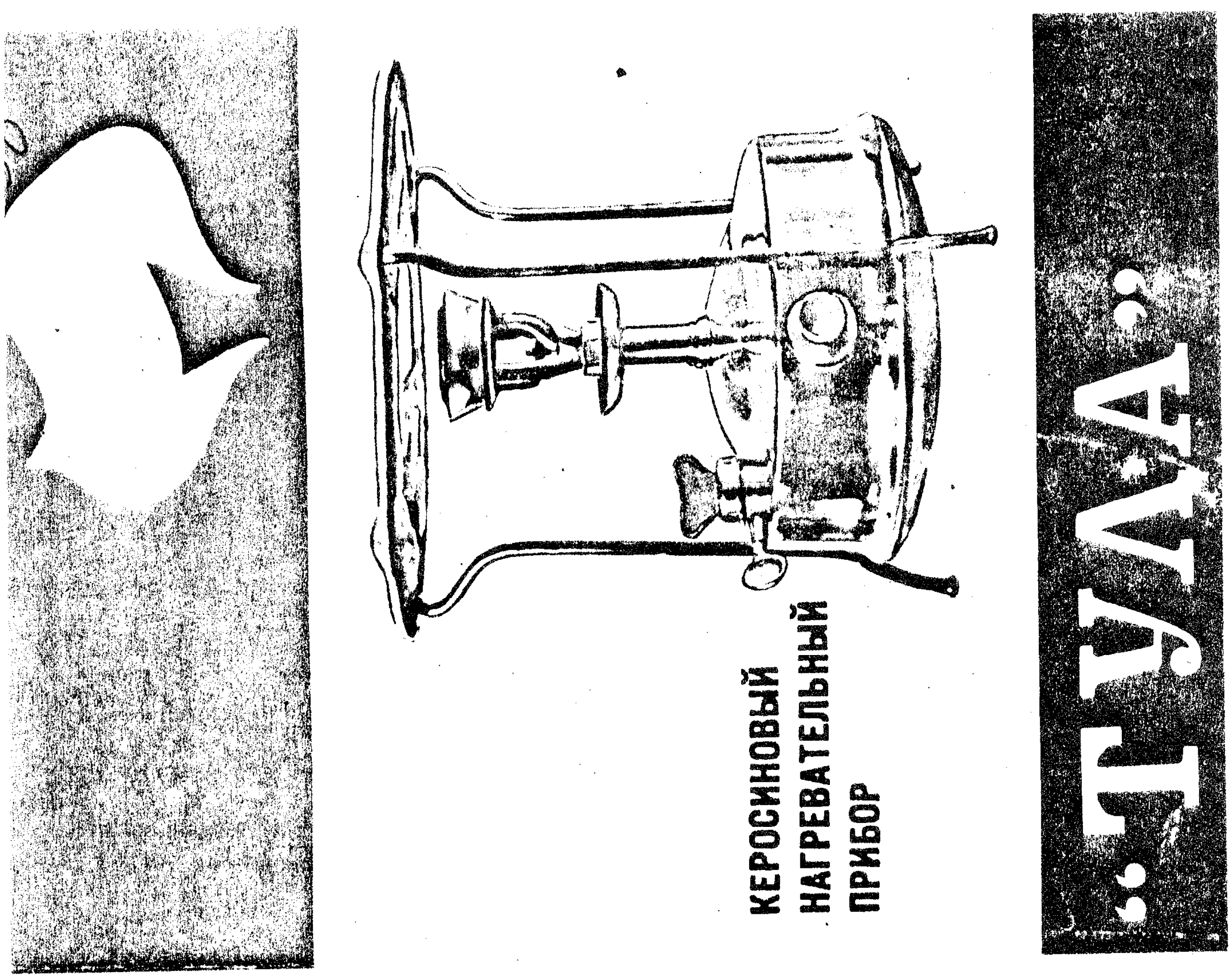
Annby
(13-15)


ANNBY STOVE
It's quality has been proved on the Mt.Himalaya by the Korean alpinists in 1981.
ANNBY brand means high quality stove.
ANNBY STOVE is most suitable for heating and cooking as comfortable as cooking in the house kitchen with the simple handling and operating under any atmospheric conditions of rainy, windy, cold lack of the air.
•Automatic Quick-lighter
Charactics of the ANNBY STOVE
1. Equipped with special one-toucn Automatic Quick-lighter for instant preheating
2. Kerosene oil is used for both fuel and preheating
3. Without alcohol nozzle is automatically cleaned and its flame is also regulated
4. Equipped with level gauge to be operated under the high pressure and temperature
5. Equipped with a durable polyurethane-seal air-pump
6. Equipped with a safety valve against over pressure
7. Outter case helps you to carry it easily without the extra-handling
•Model No.L747
Patented, and pending
1. Patent No. 19323, 34980, 34981
2. Patent pending in U.S.A., Sweden, W/Germany, England, Japan and Taiwan
•Outter Case
•Model No.105
DAERIM is proud of the Golden and Silver Medals awarded in the International Technical Exhibitions.
•Golden Prize-5th Annual International Inventor's Expo'81 (the city of New York)
•Golden Prize-8e Salon International des Inventions et des Techniques Nouvelles Geneve'79
•Silver Prize- 9e Salon International des Inventions et des Techniques Nouvelles Geneve'80
•National Prize of the Industry, the Republic of Korea, 1981
DIPLÔME

Annby
(13-15)


ANNBY STOVE
with small automatic quick-lighter
awarded in
International Exhibitions of
Inventions at Geneve &
New York'79,'80,'81.
DAERIM GAS COMPANY, LTD., SEOUL, KOREA
4214, Shingil-Dong, Youngdeungpo-Ku, Seoul, Korea. Central P.O. Box 8920, Seoul Tel.: 833-3661—3,
834-1035—6 Telex: K25666 "NAM" PAT. SEOUL

Primus (USSR)
(15-38)

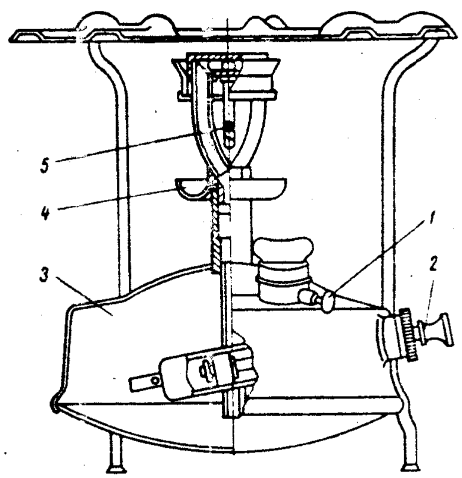


ВНИМАНИЕ!

Прибор „Тула" работает устойчиво и надежно только при использовании осветительного керосина.

ЗАЖИГАНИЕ ПРИБОРА

Подготавливая прибор к работе, в резервуар *3* надо налить 3/4 литра керосина, прочистить форсунку *5*, подогревательную чашку *4* заправить денатурированным или сухим спиртом или керосином и зажечь.



При догорании спирта завернуть ключ *1*, слегка накачать в прибор воздух (3—5 ходов штока *2*), после чего поджечь пары керосина над верхней частью горелки. Дав горелке в течение 1/2—1 минуты хорошо прогреться, накачать в прибор воздух до нормального горения. Интенсивность горения регулируется ключом *1* и штоком *2*.

Если из форсунки пойдет керосин (в случае недостаточного прогрева горелки), выпустить воздух, отвернув ключ, и повторить разогрев горелки.

Чтобы прибор работал надежно, надо периодически очищать горелку от копоти, применять профильтрованный осветительный керосин. В качестве фильтра могут быть применены вата, марля и мелкая сетка (шелковка).

Во избежание преждевременного засорения отверстия в форсунке не рекомендуется разжигать прибор, накачивая керосин в подогревательную чашку через форсунку горелки.

При длительной работе прибора рекомендуется периодически выпускать из резервуара часть нагревшегося воздуха и подкачивать свежий.

Если насос плохо нагнетает воздух, нужно извлечь шток с поршнем, расправить борт кожаной манжеты и смазать ее каким-либо минеральным маслом или рыбьим жиром.

ВО ИЗБЕЖАНИЕ НЕСЧАСТНЫХ СЛУЧАЕВ НЕЛЬЗЯ:

Заправлять прибор бензином, газолином и другими горючими жидкостями.

Наливать керосин в неостывший прибор.

Пользоваться прибором на деревянном столе без огнестойкой прокладки.

Разжигать и ставить работающий прибор ближе 50 *см* от легкозагорающихся предметов и деревянных перегородок.

Развешивать над прибором, когда он работает, одежду, белье и другие предметы.

Держать запасы керосина в непосредственной близости от прибора.

Оставлять работающий прибор без присмотра.

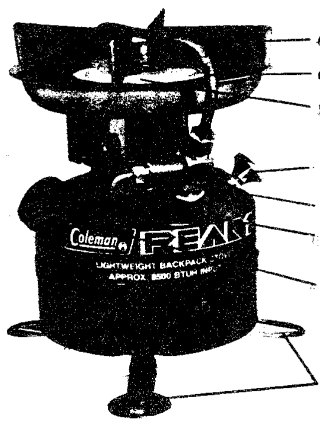
ТЕХНИЧЕСКИЕ ДАННЫЕ

Емкость резервуара, *л*	1
Габаритные размеры (с решеткой), *мм*:	
диаметр	215
высота	222
Вес прибора (без керосина), *кг*	1,4
Время закипания 2 *л* воды, *мин*	не более 15

ПРИНАДЛЕЖНОСТИ

К каждому прибору прикладываются:

Иголки для прочистки форсунки	3
Ключ для смены форсунки	1
Ключ для смены горелки	1
Запасная форсунка	1
Запасной ключ для выпуска воздуха	1
Инструкция по эксплуатации и уходу	1



1 Follow Instructions and Warnings To Avoid Possible Injury or Property Damage.

WARNING:

1. This stove consumes air (oxygen). Do not use in unventilated areas. Ample ventilation must be provided to avoid endangering your life. Provide additional ventilation for persons and other fuel burning appliances occupying the same enclosed area.

2. When stove is in use, all metal parts of burner assembly and controls become extremely hot. DO NOT TOUCH.

3. Fuel for your stove is extremely flammable. Use the same care as when using gasoline.

4. Never fill or light stove inside house, camper, or tent.

5. Never fill tank, loosen or remove fuel cap while stove is near flame, other heat sources or while stove is hot to the touch.

6. Use only Coleman fuel or clean, fresh, white gas. Never use fuel containing lubricating oils, lead compounds, or other metallic compounds. Some unleaded automotive fuels contain metallic compounds.

7. Store fuel in a clean, properly marked, metal container. Use and store away from flame (including pilot lights) or excessive heat.

8. Never allow tents, sleeping bags, clothing or any flammable material to come within three feet of the top and one foot of all sides of the stove.

9. Never place heavy or large capacity utensils on stove. Never alter stove in any way or use with any device or part not expressly approved by Coleman. Never use as a space heater. Never leave stove unattended while burning.

10. Never pump the stove while a utensil is on it.

11. Keep out of reach of children.

2 To Fill Tank

NEVER FILL OR LIGHT STOVE INSIDE HOUSE, CAMPER, OR TENT.

1. Extend feet and place stove on a smooth, level surface.

2. Move the **RED FUEL LEVER** to the OFF position. (Fig. 1)

3. Close **PUMP KNOB** firmly. Turn in direction of arrow on pump knob. (Fig. 2)

4. Remove **FUEL CAP**. Use a funnel or suitable filling device and fill with clean, fresh fuel. **DO NOT TIP STOVE.** (Fig. 3)

5. Replace **FUEL CAP** on stove and on fuel container. Tighten firmly. Move fuel container away from stove **WIPE UP ANY SPILLED FUEL AND DISPOSE OF IN A SAFE PLACE.**

Fig. 1

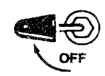
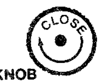


Fig. 2



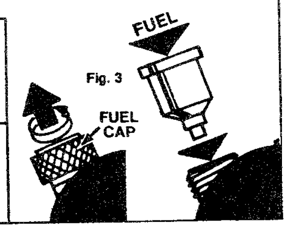


Fig. 3

3 To Pump

1. Make sure **RED FUEL LEVER** is in the OFF position. (Fig. 4)

2. Open **PUMP KNOB** one turn.

3. With thumb over hole in **PUMP KNOB**, pump approximately 25 full strokes.

4. Close **PUMP KNOB** firmly.

Fig. 4

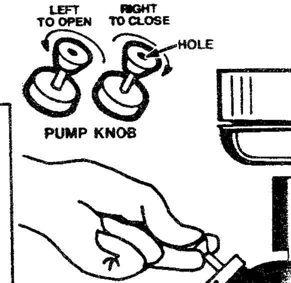


Fig. 5

4 To Light

For Temperatures below freezing, see note below.

1. Place stove on a smooth, LEVEL surface.

2. Move **BLACK FLAME ADJUSTMENT LEVER** to the "LIGHT/HI" position. (Fig. 6)

3. First hold lighted match at burner and THEN turn RED FUEL LEVER straight down to "LIGHT". (Fig. 7)

4. As soon as burner lights, open **PUMP KNOB** one turn and pump for ONE FULL MINUTE (60 pumps). Close **PUMP KNOB.**

CAUTION: If fuel or flames appear below burner, immediately turn **RED FUEL LEVER** "OFF". Allow stove to cool. Turn stove upside down to empty any fuel that accumulated in the burner. Wipe dry. Carefully review instructions before relighting stove.

5. Turn **RED FUEL LEVER** to "RUN". (Fig. 7)

6. Adjust flame to desired heat with **BLACK FLAME ADJUSTMENT LEVER**. Additional pumping may be required for full heat output.

NOTE: **IN TEMPERATURES BELOW FREEZING PREHEATING IS REQUIRED.** Place generous amount of preheating paste on burner cap beneath the generator (Fig. 8). Light the paste. After the paste is almost consumed, follow the above lighting instructions.

BLACK FLAME ADJUSTMENT LEVER

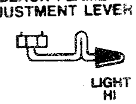


Fig. 6

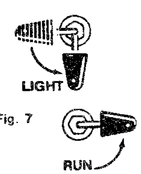
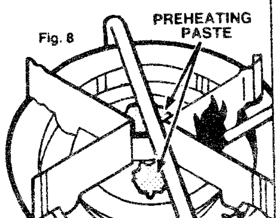


Fig. 7

Fig. 8



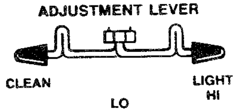
5 To Turn Off

1. Move **BLACK LEVER** from CLEAN to HI several times. Leave lever in HI position (Fig. 9)

2. Latch **RED LEVER** in OFF position. (Fig. 10)

Fig. 9

BLACK FLAME ADJUSTMENT LEVER



RED FUEL LEVER

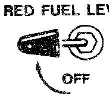
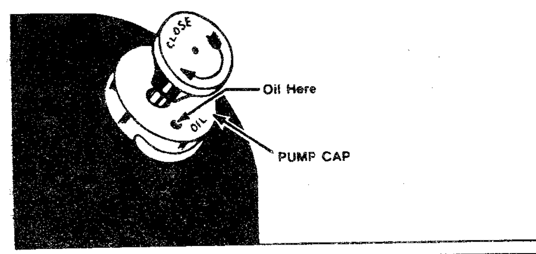


Fig. 10

Things You Should Know

- **PREHEATING PASTE** is available at most stores that sell backpacking equipment.
- To reduce the possibility of rust and corrosion, flush tank and refill frequently with fresh fuel.
- During operation for an extended period at a low heat setting, you may notice an intermittent yellow flame. This can be corrected by adjusting the flame to a slightly higher level with the **BLACK LEVER.**
- Periodically check the tightness of the packings and if necessary, tighten the **PACKING NUTS** on the **RED** and **BLACK LEVERS** just enough to prevent leaks.
- Periodically squirt a few drops of oil into the oil hole in the **PUMP CAP.** This will keep the pump functioning properly.



How to Use and Enjoy Your Lightweight Backpack Stove Model 400-499

U.S. PATENT NO.
3933146, 4126117

Coleman PEAK 1®

Limited 1 Year Warranty

This product is warranted to the retail consumer for one year from date of retail purchase against defects in material and workmanship and is transferable. If a Customer Information Card is enclosed please return it so that we may reach you in the unlikely event that a safety recall is needed. Return is not required to validate this warranty.

WHAT IS COVERED: Replacement parts and labor. Transportation charges to Consumer for repaired Product.

WHAT IS NOT COVERED: Transportation charges to Coleman for defective Product. Damages caused by abuse or failure to perform normal maintenance — see owner's manual. Sales outside of the United States. Any other expense. Consequential damages, incidental damages, or incidental expenses, including damage to property. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

HOW TO OBTAIN WARRANTY PERFORMANCE: Locate nearest Coleman Service Center by calling 1 800/835-3278 TOLL FREE! Attach to Product your name, address, description of problem, phone number and proof of date of retail purchase (sales slip). Package and return Product to Coleman Service Center, transportation charges prepaid.

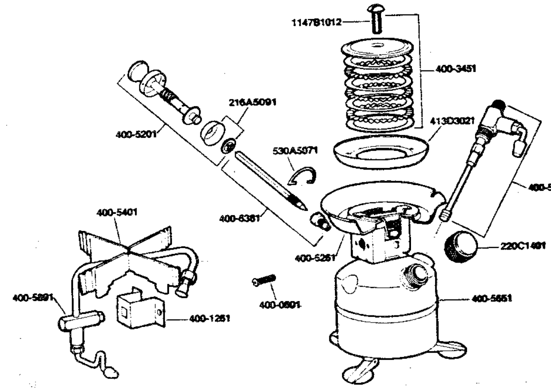
IMPLIED WARRANTIES: Any implied warranties, including the implied warranties of merchantability and fitness for a particular purpose, are limited in duration to one year from date of retail purchase. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you.

To the extent any provision of this warranty is prohibited by federal, state, or municipal law and cannot be preempted, it shall not be applicable. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

THE COLEMAN COMPANY, INC. 445 N. Minnesota Wichita, Kansas 67214

Made in United States of America
THE COLEMAN COMPANY, INC.
General Office and Factory: Wichita, Kansas U.S.A. 67201
Canadian Office and Factory: Toronto, Canada
960A391 (10-80)
LITHO IN U.S.A.

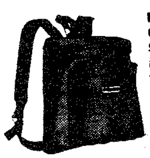
Parts List for Coleman Peak 1 Lightweight Backpack Stove Model 400-499



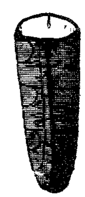
PART NUMBER	DESCRIPTION
1147B1012	Screw, Burner Cap
220C1401	Filler Cap
400-0601	Screw (Pkg. of 6)
400-1261	Generator Bracket
400-3451	Burner Ring Set
400-5201	Pump Plunger
400-5261	Burner Box Assembly
400-5401	Grate
400-5571	Valve Assembly
400-5651	Fount
400-5891	Generator & Regulator Assembly
400-6381	Air Stem & Check Valve
413D3021	Burner Bowl
530A5071	Clip for Pump Cap
216A5091	Pump Cut and Nut

Other Peak 1 Products and Accessories

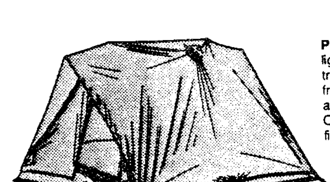
Model 770 Double Compartment, Five Pocket Pack. Made of Cordura® nylon, it comes with a detachable fanny pack that adds 400 cubic inches of storage. The Flexible Live-Load® frame firmly supports your load.



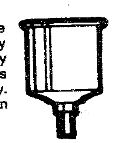
Model 720 Single Compartment Day Sack. Ideal size for many trips and perfect fit for binders and books. Haul strap comes standard.



Peak 1® Sleeping Bags. Choose from four models in two configurations, mummy or taper — all filled with DuPont Dacron® Hollofil® II. Cover and lining are ripstop nylon for superior wear. All bags are machine washable.



Peak 1® Two- and Four-man Tents are light-weight, rugged, and give unusually roomy trail protection. Although they are completely free-standing, both grommeted nylon straps and loops are provided for additional stability. One man can erect either model in less than five minutes.



Filtering Funnel, 199B-1111, aluminum with strainer and filtering fabric. Removes water, dirt, impurities from fuel. Replacement Filter 199-1091.

Principles of Operation

The stove consists of four main components: The **TANK, PUMP, FUEL VALVE** and **GENERATOR.**

The **TANK** is designed to hold both the fuel and air. To avoid a fuel leak during lighting, an adequate air space **MUST** exist above the fuel level in the tank. Never overfill tank as this will decrease the needed air space. To avoid overfilling, **ALWAYS fill** stove on a level surface. Never tip stove on its side in an attempt to pour extra fuel in the tank.

The **PUMP** pressurizes the fuel tank. Opening the pump knob one turn allows air to be pumped past a check valve and into the air space above the fuel.

The **FUEL VALVE** controls the flow of fuel and air from the tank to the generator. This valve has three positions: "OFF", "LIGHT", and "RUN". The "OFF" position closes the fuel valve and prevents fuel flow. The purpose of the "LIGHT" position is to heat the generator sufficiently to vaporize fuel that is passing through it on the way to the burner. In the "LIGHT" position, both fuel and air from the tank pass through the fuel valve. As soon as the stove lights, it is important that additional air be pumped into the tank to replace the air that is passing through the fuel valve. Pump for at least ONE FULL MINUTE. Time your pumping so that you pump one stroke per second or about 60 strokes per minute.

After pumping for a minute, the generator will be hot enough to turn the fuel lever to "RUN". In the "RUN" position, fuel only passes through the fuel valve as air is no longer withdrawn from the tank.

The function of the **GENERATOR** is to absorb heat from the burner and vaporize the liquid fuel passing through the generator. Attached to the end of the generator is the flame adjustment mechanism. Moving the flame adjustment lever from "CLEAN" to "LIGHT/HI" moves a needle in and out of a small orifice in the end of the generator. The needle both cleans the orifice and regulates the flow of fuel. Always light the stove with the flame adjustment lever in the "LIGHT/HI" position so that the stove is delivering full heat output to the generator.

If you notice an intermittent yellow flame when operating at a low heat setting, move the flame adjustment lever to a slightly higher setting. This will increase the heat on the generator and eliminate the yellow flame.

The fuel valve lever and the flame adjustment lever pass through packing nuts into the valve bodies. Behind each packing nut is a packing, or gasket material. The purpose of the packings are to put tension on the levers so they don't move too easily and also to prevent fuel from leaking around the levers. If the levers loosen up from use or if a fuel leak should occur, tighten the packing nuts approximately one half turn.

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APPENDIX 3. ERROR ESTIMATES IN POWER AND EFFICIENCY CALCULATIONS

The instruments used in the work have specific lowest values that they can measure. These are known as least counts. This introduces an error into the results calculated from measurements. In this appendix we shall indicate the method used in estimating the upper bound for errors in the results presented in the work. The quantities calculated in this work are power output, energy absorbed by the water in the pan and the efficiency. These are given by:

$$P_s = m_f B/t \tag{A3.1}$$

$$E_w = (T_{100} - T_i)C_p m_i + m_e H \tag{A3.2}$$

$$\eta = \frac{E_w}{m_f B} \cdot 100 \tag{A3.3}$$

The various symbols used in (A3.1) to (A3.3) are defined below.

P_s : Power of the stove, kW
B : Calorific value of the fuel, kJ/kg
t : Time of burning, s
m_f : Mass of fuel consumed during t, kg
E_w : Energy absorbed by the water in the pan, kJ
T_{100}: Boiling temperature, taken as 100° C
T_i : Initial temperature, ° C
C_p : Specific heat of water, 4,186 kJ/kg K
m_i : Initial amount of water, kg
m_e : Evaporated amount of water, kg
H : Latent heat of evaporation, 2257 kJ/kg
η : Efficiency, %

The error introduced into the calculation of a given quantity Y, which is derived from three measurements x_1, x_2 and x_3, is estimated as follows.

$$Y = Y(x_1, x_2, x_3)$$

$$dY = \left|\frac{\partial Y}{\partial x_1}\right| dx_1 + \left|\frac{\partial Y}{\partial x_2}\right| dx_2 + \left|\frac{\partial Y}{\partial x_3}\right| dx_3$$

Using finite difference notation these are written as

$$\delta Y = \left|\frac{\partial Y}{\partial x_1}\right| \delta x_1 + \left|\frac{\partial Y}{\partial x_2}\right| \delta x_2 + \left|\frac{\partial Y}{\partial x_3}\right| \delta x_3$$

It is conventional to present the errors in relative terms. Thus

$$\frac{\delta Y}{Y} = \{\left|\frac{\partial Y}{\partial x_1}\right| \delta x_1 + \left|\frac{\partial Y}{\partial x_2}\right| \delta x_2 + \left|\frac{\partial Y}{\partial x_3}\right| \delta x_3\}/Y \tag{A3.4}$$

The absolute signs for the partial derivatives are introduced so that the worst combination of positive and negative errors are selected for estimating errors. Thus the expression (A3.4) provides an upper bound for the errors in the quantity Y. δx_1, δx_2 and δx_3 are taken positive. Using (A3.4) we obtain the following expressions for the quantities specified by the expressions (A3.1) to (A3.3).

$$\frac{\delta P_s}{P_s} = \frac{\delta m_f}{m_f} + \frac{\delta B}{B} + \frac{\delta t}{t} \qquad \text{(A3.5)}$$

$$\frac{\delta E_w}{E_w} = \frac{E_p m_i \delta T_i}{T_i} + \frac{C_p \Delta T_i \delta m_i}{m_i} + \frac{H \delta m_e}{m_e} \qquad \text{(A3.6)}$$

$$\frac{\delta \eta}{\eta} = \frac{\delta E_w}{E_w} + \frac{\delta m_f}{m_f} + \frac{\delta B}{B} \qquad \text{(A3.7)}$$

The calorific values of the fuels used in the investigation are guaranteed to be within $\pm$ 1%. The measurement accuracies of the instruments are listed below.

Time: 2 s
Fuel weight: 2×10^{-3} kg
Initial temperature: 1° C
Initial amount of water: 2×10^{-3} kg
Evaporated amount of water: 4×10^{-3} kg

This information is used below to obtain the error estimates for a few typical results.

Stove: Annby (13-15)
P_s = 3,59 kW
m_f = 0,143 kg
t = 1732 s

$$\frac{\delta P_s}{P_s} = 3\%$$

Stove: Prabhakar (10-13)
P_s = 0,26 kW
m_f = 0,041 kg
t = 8191 s

$$\frac{\delta P_s}{P_s} = 6\%$$

Thus we can state that the maximum errors in the power output results obtained in this investigation are about 6%. These occur in the minimum power (P_{min}) calculations. P_{max} errors will be smaller than 6%.

Efficiency errors have been estimated for two cases - one for an experiment terminated at the boiling point and the other for an experiment continued into the boiling regime.

Stove: Swan 20 (8-36)

P_s = 1,66 kW

m_i = 6,400 kg (4 pans were brought to boil successively)

Case 1

m_e = 0,047 kg

m_f = 0,126 kg

t = 3309 s

T_i = 20° C

$\frac{\delta\eta}{\eta}$ = 6%

Stove: Swan 20 (8-36)

P_s = 1,70 kW

m_i = 4,106 kg (2 pans of 2,053 kg each were used)

Case 2

m_e = 1,169 kg

m_f = 0,213 kg

t = 5490 s

T_i = 20° C

Each pan was held at boiling point for 30 minutes.

$\frac{\delta\eta}{\eta}$ = 3%

The efficiency estimates in this report have a maximum relative error of 6%, excepting perhaps Divyajyoti (4-12). The errors are usually smaller in experiments where the test is prolonged for ½ an hour or more into the boiling regime.

In addition to instrumental errors discussed above, every experimental work suffers from errors of judgement. One such error in the present case arises while estimating the time at which water attains boiling temperature. In our normal work we use automatic temperature and fuel weight loss recordings to estimate these accurately. In view of the large number of stoves tested in this programme in a short time, this was rejected as impracticable. Instead the start of continuous escape of steam at the lid corners was taken to be the attainment of boiling temperature. Roughly this is analogous to the behaviour with a whistling kettle. While this is not an exact procedure, we believe that it is sufficiently simple and is capable of producing reproducible results. A thermometer could have been used and one could have kept watch over it. This proved cumbersome for the type of experiments done here. We were running simultaneous tests on 3 or 4 stoves at a time and in addition several pans of water were brought to boil on each stove.

The other type of judgement error in these results were in the power tests where simultaneous recording of weight and time are required.

Such errors were held to a minimum since in most of the experiments reported here two people were present during measurements.

It is our belief that the results reported here do not suffer from any significant judgement errors since adequate number of repeat measurements were carried out.

APPENDIX 4. PRINCIPAL PROPERTIES OF THE FUELS USED IN THE TEST PROGRAMME

There are many properties that a substance has to possess for it to qualify as a domestic fuel. Standards for the properties have been evolved over the years in many countries for domestic fuels. These standards have been incorporated into commercial practice and it is fair to state that the fuels supplied by different companies in an overall sense meet these specifications to an acceptable degree. We shall not present these specifications here, but refer the reader to standard handbooks that provide such information. We shall satisfy ourselves here with presenting only calorific values and specific gravities since these are directly used in the testprogramme and calculations associated with it. Table A4.1 presents this information.

Table A.4.1 Properties of fuels used in the test programme

Fuel	Calorific value[1] kJ/kg	specific gravity[2] kg/l
Kerosene	43530	0,790 at 19° C
Petrol (normal)	42950	0,802 at 15° C
Alcohol (ethanol, 85%)	20050	0,790
Camping gas (butane)	45700	0,58 at 15° C
Propane	46200	0,51 at 15° C

Notes: 1. All calorific values are the lower values, ie. corrected for moisture condensation.
2. Specific gravity is temperature dependent.

Sources: Eindhovense Olie Centrale (Eindhoven Oil Centre), Shell Information Centre, Rotterdam
Gist Brocades, Den Haag.

APPENDIX 5. ESTIMATION OF FUEL CONSUMPTION FOR COOKING

In this appendix we present a simple theory to convert the power and efficiency test results obtained from water boiling experiments into fuel consumption estimates for specified cooking tasks. The theory, in particular, will assist in understanding our claim that the P_{min} plays a vital role in determining the fuel consumption for many cooking processes.

A5.1. Theory.

The energy required to cook n food ingredients in a medium m can be conveniently split up into four component parts.

(i) Energy required to raise the medium to the cooking temperature from the ambient.

$$E_{c,m} = M_m C_{p,m} (T_{m,c} - T_i), \text{ kJ} \qquad (A5.1)$$

where M_m = mass of the medium, kg.
$C_{p,m}$ = specific heat of the medium, kJ/kg.^{o} C
$T_{m,c}$ = cooking temperature, ^{o}C
T_i = initial (ambient) temperature, ^{o}C

(ii) Energy required to raise the food ingredients to their cooking temperature from the ambient.

$$E_{c,F} = \sum_{j=1}^{n} M_{F,j}\, C_{p,j}\, (T_{F,c} - T_i), \text{ kJ} \qquad (A5.2)$$

The symbols are the same as in (A5.1). Different subscripts are used to denote different quantities. We would like to draw the attention to $T_{F,c}$ the cooking temperature; it can be different from $T_{m,c}$ (see Verhaart 1982 for a discussion in connection with the preparation of French fried potatoes).

(iii) Energy required in the production of watervapour

$$E_{c,e} = M_e H \quad \text{kJ} \qquad (A5.3)$$

M_e has to be determined by weighing the food and medium before and after cooking.

The water vapour could be formed either from the medium (when it is water or milk or such other dairy product) or from food ingredients (in particular vegetables, meat and fish have large quantities of water in them). Thus most of the cooking processes will involve the production of water vapour whatever the cooking medium be.

(iv) Energy absorbed by the chemical process that accompanies cooking.

$$E_{c,c} = \sum_{i=1}^{n} M_{F,i} K_{F,i} \quad \text{kJ} \qquad \text{(A5.4)}$$

where $K_{F,i}$ is the chemical energy necessary for the conversion of raw into cooked food.

Thus the total energy required for the completion of a cooking task is given by

$$E_c = E_{c,m} + E_{c,F} + E_{c,e} + E_{c,c} \qquad \text{(A5.5)}$$

The fuel necessary to accomplish this task is given by

$$M_f = \frac{E_c}{\eta B} \qquad \text{(A5.6)}$$

This expression shows that M_f is reduced by increasing η, but also by reducing E_c. Both these can be to a great extent influenced by the stove design.

In the expression (A5.5), $E_{c,c}$ and $E_{c,F}$ are independent of the stove design being determined by the quantity and chemical/physical properties of the food to be cooked. However $E_{c,m}$ and $E_{c,F}$ are strongly influenced by the stove design as the discussion below will demonstrate.

We will restrict the discussion to situations where water is the cooking medium.
In fact water is the principal cooking medium for a large number of dishes prepared in the world. The maximum temperature that one could expect in the cooking process with water as the cooking medium is 100^o C at atmospheric pressure. The cooking recipes practiced around the world call for holding the food mixture at or around this temperature for a certain period. The period itself is determined by the temperature (higher temperatures are possible with pressure cooking and thus lower periods) and the type of food cooked. The periods, as far as we understand now, are the lowest for flours and highest for dried beans. The energy supplied during this period fulfills two purposes: the chemical energy needed for cooking and to make up for the heat losses from the pan to see that the food mixture is maintained at boiling temperature. The former requires chemical data and is known to be small, compared to the other energies involved in the process. The latter is dependent on so many factors and we will provide an estimate for this in what follows.

Fig. A5.1 shows heat flows into and from the pan located on the top of a stove. The bottom of the pan receives heat while the lid (or top surface of the food mixture when there is no lid) loses heat. The pan side is a more difficult question. The pan side for the stove designs considered here is covered by the rising hot

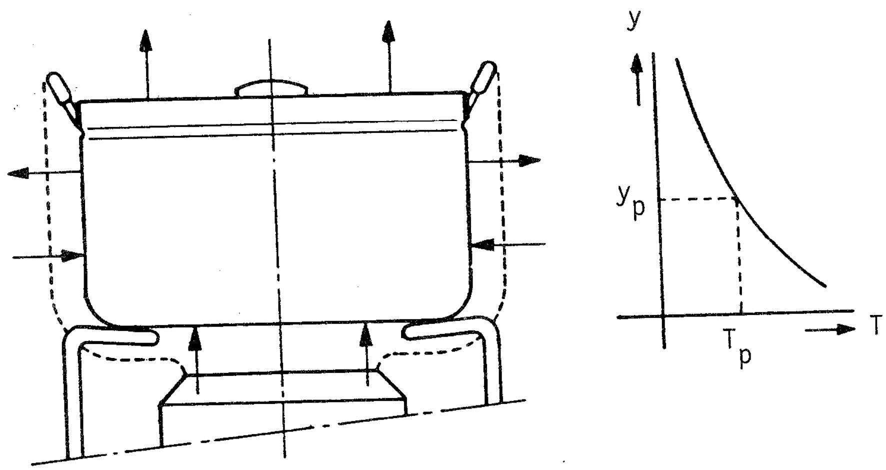

Fig. A5.1 heat balance on the pan

gas column from the combustion zone. This gas cools down as it rises due to two reasons: heat transfer to the pan and entrainment of cold air from the surroundings. It is quite possible that at some point Y_p along the pan (see figure A5.1) the temperature will fall below that of the pan. Thus the pan side below Y_p will receive heat, but above Y_p will lose heat. Exact location of Y_p is too cumbersome to estimate and we will be satisfied with some ball park estimates.

De Lepeleire (1983) estimated that the heat loss from an aluminium lid will be 700 W/m^2. Noting from figure A5.1 that the temperature difference driving the heat transfer will be lower for the pan side, and further that not all the area of the pan side may be losing heat, the pan side heat loss may not be higher than 350 W/m^2. On these assumptions table A5.1 has been constructed for the heat losses from the different pans used in this investigation.

Table A5.1 Heat loss estimates from pans

Sl. No.	Pan size (cm)		heat loss (watts)
	diameter	height	
1	14	7,5	22
2	16	8,5	29
3	18	10,1	38
4	20	11,0	46
5	24	12,6	65

It is instructive to compare the figures in this table with P_{min} values in table 3.1. The lowest value recorded for P_{min} in that table is for the pool burner, Optimus 77A, and it has a P_{min} of 160 Watts. At about 50% efficiency, this stove pumps 80 Watts into the pan. This stove uses a 16 cm pan whose heat loss is 29 Watts according to table A5.1.

The 16 cm pan is just sufficient to cook about 0,4 kg rice. The chemical energy required to cook rice is about 170 kJ/kg (Geller & Dutt, 1983). Assuming the cooking takes ½ an hour, this corresponds to about 37 Watts. Thus the total power required to cook this rice in this pan is 66 Watts while 80 Watts are pumped into the pan. This situation can be considered acceptable.

On the contrary if we consider Primus 505 it has a P_{min} of 840 Watts and uses a 20 cm pan. Again with an efficiency of 50% it pumps 420 Watts into the pan. Heat losses are 46 Watts from Table A5.1. It can cook about 0,8 kg of rice (as determined by the pan) which means about 74 Watts for the chemical conversion. Thus 120 Watts are necessary for cooking, but 420 Watts are supplied to the pan. The extra 300 Watts are used up for simply evaporating the water.

The above situation has a second consequence. In order to obtain the same quantity of cooked food, one needs to start with a larger quantity of water to make up for the loss of water by evaporation. This additional water needs to be heated to boiling temperature.

If one were to compute the energies consumed by the two stoves (see below), it turns out that Optimus 77A uses 804 kJ/kg of cooked rice while the Primus uses 1490 kJ/kg. This forms the basis of our emphasis on P_{max}/P_{min} ratios.

This also shows why the chemical energy for converting raw rice to cooked rice can be neglected. 1 kg of cooked rice has only 0,4 kg of raw rice. Thus the chemical energy used for producing 1 kg of cooked rice is 68 kJ. It is 8,5 and 4,6 % respectively for the two stoves concerned. Such low powers as 160 Watts is quite hard to realize in an average stove with a P_{max} of 1,5 kW or so. Thus we neglect this in our further work.

Note that P_{max} does not enter into the fuel consumption calculations. It only determines the heating period, $t_{r,h}$, given by

$$t_{r,h} = \frac{E_{r,h}}{P_{max}\ \eta_{max}} \quad s$$

Thus the total fuel consumption for cooking rice is

$$M_r = M_{r,h} + M_{r,s} \quad kg$$

For lentils and vegetables mixture, a similar procedure leads to the following formulas

$$M_{l,s} = \frac{P_{min}.3600}{B} \ kg$$

$$y_{l,s} = \frac{P_{min}.3600.\eta_{min}}{H} \ kg$$

$$E_{l,h} = [(1,7\ x_l + y_{l,s})\ C_{p,w} + x_l C_{p,l} + x_v C_{p,v}] \ . \ (T_{100} - T_i) \ kJ$$

$$M_{l,h} = \frac{E_{l,h}}{\eta_{max}\ B} \ kg$$

$$t_{l,h} = \frac{E_{l,h}}{P_{max}\ \eta_{max}}$$

$$M_l = M_{l,s} + M_{l,h}$$

The specific fuel consumption is calculated on the basis of the so-called water equivalents of all the foods cooked.

Total quantity of cooked food is

$$Q_f = x_r \frac{C_{p,r}}{C_{p,w}} + x_l \frac{C_{p,l}}{C_{p,w}} + x_v \frac{C_{p,v}}{C_{p,w}} + 1,7\ x_l + 1,13\ x_r$$

Total quantity of fuel used is

$$M_f = M_r + M_l$$

Thus the specific fuel consumption is

$$SFC = \frac{M_f}{Q_f} \ \text{kg of fuel/kg water equivalent of the food cooked.}$$

Note that P_{max} does not enter into the fuel consumption calculations. It only determines the heating period, $t_{r,h}$, given by

$$t_{r,h} = \frac{E_{r,h}}{P_{max}\ \eta_{max}} \quad s$$

Thus the total fuel consumption for cooking rice is

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$$y_{l,s} = \frac{P_{min}.3600.\eta_{min}}{H} \ kg$$

$$E_{l,h} = [(1{,}7\ x_l + y_{l,s})\ C_{p,w} + x_l C_{p,l} + x_v C_{p,v}] \ . \ (T_{100} - T_i)\ kJ$$

$$M_{l,h} = \frac{E_{l,h}}{\eta_{max}\ B} \ kg$$

$$t_{l,h} = \frac{E_{l,h}}{P_{max}\ \eta_{max}}$$

$$M_l = M_{l,s} + M_{l,h}$$

The specific fuel consumption is calculated on the basis of the so-called water equivalents of all the foods cooked.

Total quantity of cooked food is

$$Q_f = x_r \frac{C_{p,r}}{C_{p,w}} + x_l \frac{C_{p,l}}{C_{p,w}} + x_v \frac{C_{p,v}}{C_{p,w}} + 1{,}7\ x_l + 1{,}13\ x_r$$

Total quantity of fuel used is

$$M_f = M_r + M_l$$

Thus the specific fuel consumption is

$$SFC = \frac{M_f}{Q_f}$$ kg of fuel/kg water equivalent of the food cooked.

This value provides a convenient comparison for different food types and stoves.

In order to use these formulae we need to know the C_p values for different foods. These are reproduced from Geller & Dutt (1983) in Table A5.2.

Table A5.2 Specific heat of selected foods (a)

Food	Moisture content (wet basis)	Specific heat (b) (kJ/kg^o C)
Rice	10,5 - 13,5	1,76 - 1,84
Flour	12 - 13,5	1,80 - 1,88
Bread	44 - 45	2,72 - 2,85
Lentils	12	1,84
Meat	39 - 90	2,01 - 3,89
Vegetable oil		1,46 - 1,88
Milk	87,5	3,85
Carrots	86 - 90	3,81 - 3,93
Onions	80 - 90	3,60 - 3,89
Potatoes	75	3,51
Apples	75 - 85	3,72 - 4,02

This is the basis on which the results of table 6.8 have been computed. Three meals have been used in the table according to the pan sizes. These are indicated in table A5.3.

Table A5.3 Meal quantities for fuel consumption calculations in Table 6.8

sl. no.	pan size cm.	meal design ation	rice kg	lentils kg	vegetables kg	cooked food kg
1	24	I	1,5	0,75	0,75	4,6
2	18	II	0,75	0,4	0,4	2,4
3	20	III	1,0	0,5	0,5	3,1

The cooked food quantities are all water equivalents as defined earlier.

A5.3 Siwatibau cooking test results and present method of computation

We shall present a comparison between the result obtained from the present method of calculation and the cooking test results of Siwatibau (1981). She carried out cooking tests on several meals with several stoves. We shall pick one meal (Indian 1) and one stove (Hong Kong 10 wick). The ingredients for the meal were:

Rice	381 g
Potatoes	305 g
Onions	28 g
Garlic	6 g
Curry powder	18 g
Cooking oil	28 g
Fish	110 g
Water (for rice)	970 ml
Water (for tea)	1950 ml
Water (for curry)	140 ml

(rice, fish curry, tea)

The fuel consumed for this meal on the Hong Kong 10 wick stove was 164 ml or 1464,7 kcal (6122 kJ). This wick stove was stated to have a maximum efficiency of 29% as determined by the water boiling test.

The energy for cooking rice:
the water quantity used for cooking the rice is known. But Siwatibau does not provide the final quantity of cooked food. If we assume the ratios similar to ours prevail in Fiji as well,

$$y_{r,s} = 0{,}97 - 1{,}13 \times 0{,}381 = 0{,}54$$

Energy taken up by the steam $= y_{r,s} \times H = 0{,}54 \times 2257 = 1217$ kJ

Energy supplied by the stove $= 1217/\eta = 1217/0{,}29 = 4198$ kJ

Energy to heat the rice water mixture $= (0{,}381 \times 1{,}8 + 0{,}97 \times 4{,}18)75 = 304{,}1$ kJ

Energy supplied by the stove for heating the rice-water mixture $= 304{,}1/\eta = 1048$ kJ

Energy to heat the fish-potato-water mixture $= (0{,}305 \times 3{,}5 + 0{,}110 \times 3{,}5 + 0{,}14 \times 4{,}18)75 = 153$ kJ

Energy supplied by the stove for heating the fish-potato-water mixture $= 153/0{,}29 = 527$ kJ

Assuming that a third of the water got evaporated during the making of curry,

$$\text{Energy for steam formation} = \frac{0,140}{3} \times 2257$$

$$= 105 \text{ kJ}$$

Energy supplied by stove for steam formation = 105/0,29 = 363 kJ

Energy to heat the tea water = 1,95 x 4,18 x 75
= 611 kJ

Energy supplied by stove to heat the tea water = 611/0,29 = 2108 kJ

We ignore the other ingredients involved in the cooking process as insignificant from the energy point of view.

Total energy supplied by the stove to accomplish the cooking task = 8244 kJ

This is 2122 kJ or 35% more than the experimental value. We believe that this is a reasonable agreement since:

(i) the final weights of the cooked food were not given by Siwatibau, and
(ii) we had to make a guess on the specific heat of fish (made on the basis that the major consistuent of fish is water).

We will finally estimate the SFC for the Hong Kong wick stove. It turns out to be about 43 g/kg of cooked food. Compared with the entries in Table 6.8, it behaves something like the Lark. A word of caution here would not be out of place. In the Siwatibau test about 1/4 of the total heat supplied by the stove was taken up by the heating of tea water. This does not bring the concept of P_{min} in the picture. If this had been included in the meals for which Table 6.8 has been computed, then the SFC figures would have been much lower. Let us consider the Lark stove to illustrate this point. If 2 kg. of water had been boiled to make tea, the additional fuel used would be 37,5 g. The total fuel used for the meal II + tea would be 75 g. The SFC would then be 17 g of fuel per kg of cooked food. In other words neither a single value of efficiency nor SFC is adequate to describe the fuel consumption characteristics of a stove. Hence our statement that three quantities are required: P_{max}, P_{min} and η. Efficiency is taken to be invariant with P.

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