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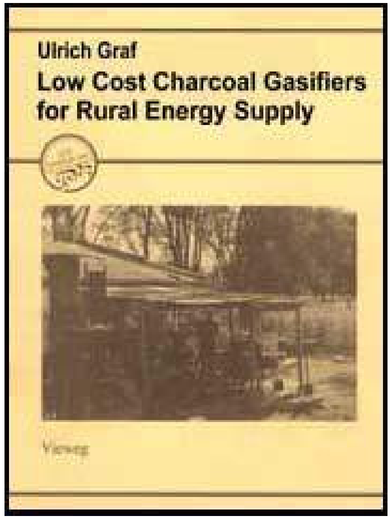

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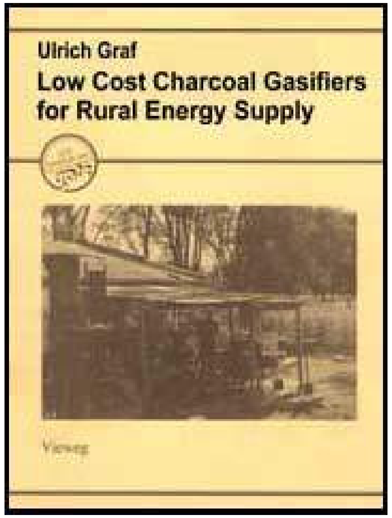

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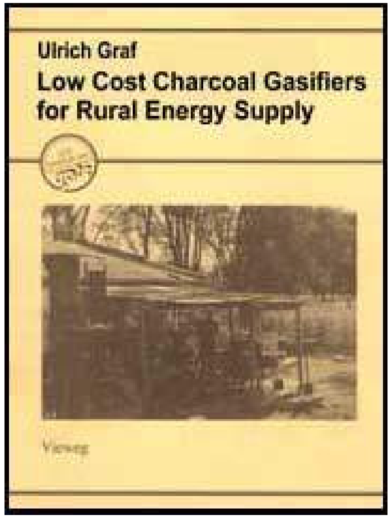


Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

8. Non-technical aspects of gasifier operation in the field

The intent of the previous chapters was it to demonstrate that it is possible to build a cost-effective and reliable gasifier for charcoal. The basic conditions for a practical application of gasifier-engine-systems in the power range 2 - 10 kW seem to be fulfilled. What else can go wrong? Some comments to nontechnical

problems, typical for situations in rural areas of developing countries, may be useful to remind of the complexity of technical co-operation.

8.1 Pro's and contras of the ''do it yourself'' approach

The fact that a ferrocement gasifier can be built at any location, using locally available materials and a few simple tools, fits perfectly into a self-help strategy for underprivileged parts of the population. In fact, encouraging proper engagement of the target group of rural development programmes helps to avoid a wide spread "gift mentality" and seems a promising approach. Some pro's and contras with respect to owner-built ferrocement gasifiers will be discussed here.

The way how to manufacture a ferrocement gasifier has so far been documented in the manual of R. Reines [9] and Alan Gonzales/ Bui Tuyen [10]. These documents are adequate to inform the scientific and technical staff of an institution, that means, to inform the later"multiplicators" of a know-how transfer. But a written manual is not helpful to people with a low educational level. The capability of people in rural areas of developing countries to read and to interprete written instructions and blueprints is very limited.

Making vessels by handling wire and cement seems to be an easy job which can be done by anyone with average skill. Basically this is true, but it should not be forgotten that the typical, interested potential user is an absolute beginner. He has, normally, to learn how to work with wire and cement mortar, but simultaneously he has to get an idea what happens in a gasifier of the type he is just building. This is more complex than it may appear. At the educational level which can be expected in developing countries, a do-ityourself approach can only

be realized with the help of well-trained instructors. Patience and care are the most important "skills" which have to be trained with any new group.

It is not only the necessary skill which has to be considered in a do-it-yourself concept. Financial aspects play an equally important role. At first glance, do-it-yourself seems to be by far the cheapest solution to acquire a gasifier. But, it has already been said that the do-it-yourself method depends on well-trained instructors. In rural development projects the salary and the travel expenses of the instructor will normally be covered by governmental institutions or donor agencies. If not, the costs of the instructor are a relevant part of the overall costs.

As soon as a relevant number of gasifiers is to be installed within a certain area (forming a "cluster" of gasifier application sites), a commercialization of the gasifier manufacturing is a recommendable way. The following principle has been tested in Bremen as well as in Argentina [1 1]: At the manufacturer's place, all the inner cylinders and attachments are completely prefabricated (see figs. p. 16). These components are transported to the site of installation. At the site, the large cooling tank is built and the final assembly is done with the participation of the later user group. In that way, the construction is done effectively by trained personnel, and the final costs are still low due to the low level of labour costs.

A summary of these considerations is:

- The do-it-yourself method is not always applicable. It is possible that the user of the plant is not interested in investing his own time and prefers to pay for it. This is realistic, considering the low labour costs in developing countries, which make the ferrocement concept so cheap.

- It is possible that manufacturing by the users (a community) is difficult to realize for reasons of insufficient availability of qualified labour.

- For the above reasons, the promotion of local manufacturers of ferrocement gasifiers has to be considered as an alternative or as a supplement to the self-help approach

- On the other hand The self help approach may not be always applicable, but at least this possibility exists. This is not the case with conventional gasifiers, which always require the facilities of a rather well equipped metal workshop. If the participation a of team of community members-preferably the later operator team-can be organized, and if the operation and maintenance of the gasifier is reasonably integrated in the economic activities of a community, the self-help approach is a unique chance to save investment costs, acquire the necessary qualification, and settle responsibility for the equipment.

8.2 Community plant or private ownership?

The existing gasifier programmes are addressed to two typical user configurations: The "community plant" and the "private owner plant". The basic conditions as well as the economic situation of these cases of ownership are remarkably different, and any dissemination strategy has to define exactly which is the target group.

a) The community plant

The most common application (expressed in numbers of installed gasifiers, for

example within the gasifier programmes in India and Thailand) is the gasifier with engine and electric generator, installed for village electrification (most of all: light and television). Typical features are:

- The financial power of the community is too low to meet the investment costs (even with a low-cost ferrocement gasifier, the costs for engine, generator and electric grid have to be considered). The installation is highly or completely subsidized by institutions or governmental agencies. This subsidy is seen as part of a compensatory activity to improve living and working conditions in economically underdeveloped regions.

- The operational costs are the salary of the operator and fuel costs. The total of the operational costs is significantly lower than the savings for kerosene and candles, used for lighting purposes before, and the users can enjoy a limited luxury like radio and television at reduced costs (no batteries and no fees for battery charging).

- The community members contribute by "cash or in kind": Typically they pay a small amount of cash and supply a certain amount of the fuel. Due to very limited and irregular income, especially the contribution by cash is irregular. This results in decreasing motivation of the operator, who is not acknowledged adequately for his job.

- As the typical village electrification system does not contribute to an increase of monetary incomes of the community, it is not considered as a first priority asset. A general feeling is that the government, who subsidized the plant, should take care of the operation as well.

The motivation of a community to maintain a gasifier powered electricity supply is very sensitive to fluctuations of the socio-economic situation. According to Jain [6], the same mechanism is valid in India as observed in Colombia [3, 4]. Electricity for lighting purposes is a unanimous demand, if village communities are asked, but nevertheless it is not a basic need. Faced with the offer to get a subsidized gasification plant, the communities take their chance to get electrification without major financial participation. Seeing this probably unique chance, they agree to take over the operational costs, e.g. the salary of the operator and the costs for fuel preparation. But, if for any reason the financial situation gets worse, the financial contribution for electric light is the first expenditure to be saved, and participation by fuel or labour does not help the operator in his specific situation.

In all reported situations in India, Thailand and Colombia where community electrification was installed by means of a gasifier and where the operation costs were left to the users, problems are reported due to irregular paying of the fees. Internal conflicts of this kind often result in idle periods of the plant and in a change of the responsible operator, when he is not longer willing to do this job. The new operator is less qualified, and further problems in operation and maintenance are to be expected.

A community installation which was fully subsidized and maintained by an institution (Jain), with the users paying only a small symbolic fee, was successful. This indicates again that not technical problems, but user behaviour is the source of trouble.

In the two community installations in Thailand, described as case studies by

Naksitte [7], the participation of the users does not seem to present major problems. The villagers contribute with charcoal as well as with electricity fees. But the positive results in Thailand are perhaps due to the fact that these installations have been installed a few month before the evaluation. During the gasifier project in Colombia, it could be observed that in the first year after installation everything is organized very well, but then, gradually, the conflict begins. These conflicts could be solved, when external advice and technical assistance by regular visits of authorities were available.

Communal electricity supply is obviously an especially difficult application, and it will not develop just by offer and demand of gasifier plants. The typical low-income-community, living mainly by subsistence agriculture, has no real chance to decide which energy plant is the most economic solution for it. The village cannot afford any energy plant. If a governmental agency wants to help this underprivileged part of the population, gasifiers can be the best solution: They are much cheaper than the connection to the public electric grid, and after the installation the system is autonomous in its fuel supply. The hardware costs of the gasifier plants with 3-10 kW electric power output are not a relevant factor for a governmental programm. It is not really a crucial question whether the specific installation costs are US $ 200.-or $ 500.-per installed kW. What makes a dissemination programme of that kind expensive are the salaries of the engaged governmental employees, the travel expenses and the organizational infrastructure.

If serious programmes for development of underprivileged regions exist, much more than energy supply is necessary. If such a programme deals with improvement of agriculture, production of marketable goods, reforestation,

communal organization - than it seems to be logical to include the appropriate energy supply, and this can mean gasifiers. In that case, a concentration of gasifiers in "clusters" of approximately 10 villages makes sense. This makes the efficient organization of the fuel supply (commercialisation of charcoal production for the gasifiers) as well as the technical back up much easier.

Even if the installation costs are not the crucial point in that situation, the ferrocement-gasifer appears to be advantageous. If the users participate in the construction, or if a local group specializes in building ferrocement gasifiers, the plants would not be a "gift" from the government. It is very probable that this results in an increase of motivation to maintain the plant, apart from the advantage that any repair of the plant is easy and that the technology of building containers and pipes in cement can be very useful for other applications.

b) The private owner plant

The gasifier run by a private owner or an institution is up to now not so numerous as the community plant, but the percentage of success seems to be much higher, as soon as there is a real economic advantage. According to the case studies in India and Thailand, the typical features are:

- The gasifiers are seen as ´´demonstration units" and installed by scientific institutions, involved in gasification research. The investment costs are subsidized. The owner does not belong to the poorest of the poor: He would be able to finance a plant on its own, but he is not sure yet that a gasifier is technically reliable enough, and that the savings in fuel costs are significant.

- It is easier for the private owner to assess the economical advantage of the gasifier. The more operational hours per year, the higher the savings in fuel costs compared to liquid fuel operation. If only light in the evening is supplied, this is not so interesting in terms of financial benefits, but it may be done as a sort of interesting experiment. If agricultural or other commercial activities are combined with the energy use (irrigation water pumping, flour mill, etc.), the gasifier becomes economically interesting.

- The private owner has a particular interest in the successful operation of the plant, he is usually more qualified than a communal operator and more flexible when repair- or maintenance problems come up. He is really testing the gasifier to see whether it is useful to save money or to give a reliable energy supply. The private owner loses interest, if the technology appears not to be reliable and needs too much care.

Generally, the motivation is much better, if a private owner (or, even better, an owner/ operator) is running the plant. In the examples reported by Jain, the use of private pump sets and electricity supply by small (3.5-7.5 kW) gasifiers was successful, if the location was remote from the electric grid, or when the electric grid was considered as unreliable. Two examples for heat application (institutional cooking) in India show positive results. An installation, run by a well organized institution to supply energy (cooking gas or electricity) to the training centers and the canteen, is more or less equivalent to ´'private ownership": The responsibilities are clear, the salaries of the employees as well, and economic advantages by reduced fuel costs are easy to monitor. It must not be overlooked, however, that CO2 is a poisonous gas, requiring careful handling of the stove.

In the case of the private owner, the investment costs are extremely important. The ferrocement concept can reduce these costs considerably. It is, however, not probable that the typical private owner will have the time and interest to build the gasifier himself. In the majority of cases he considers himself as an entrepreneur whose activities do not allow to spend three weeks in building a gasifier. In that case, a gasifier manufacturer must be able to build the plant on the location, either completely or by using prefabricated components. The typical manufacturer would not be a metal work-shop, but a firm which deals with construction elements and plastering. Such commercial manufacturers of cement gasifiers do not yet exist, and the realistic product costs are not yet verified. First estimations are lined out in chapter 9 of this report.

Of course, a gasifier means always some additional costs compared to the mere combustion engine, and it is important to keep in mind that these additional costs are not only hardware costs but increased labour costs for operation as welt But, if the gasifier is reliable enough-that means that costs and efforts for maintenance and repair are not dominated by the subsystem gasifier, but by the rest of the technical equipment (engine, additional equipment like generator, waterpump, mill etc.) -than it is just an exercise in economic calculation to assess if a gasifier is viable or not. In that case, the dissemination of the gasifier technology can be left to the market situation and depends on the specific fuel costs and the operational hours per year. Pumps sets for irrigation water, flour mills, small machinery in cottage industries are the typical applications. Institutional cooking is an interesting (but dangerous) application. Electric lighting will be more an additional use of an existing plant, but not the driving force to install a gasifier.

8.3 Qualification and motivation of the operator

Apart from very small plants (2-3 kW electric), even the private owner will not do all the work himself. Commercial units and, of course, the communal plants always are run by an operator, who is responsible for the fuel supply, starting of the plant, maintenance work and repair. The work load of the operator can vary considerably and depends on the size and the reliability of the plant.

A well designed gasifier should not need much care during routine operation: Just to fill in the fuel, ignite it, and- after 10 minutes of primary air supply by ventilation - start the engine. Once a week some cleaning and once a month a checking-that should be enough.

But energy supply and consumption means much more. In fact, especially village electrification is a very complex scheme, with the gasifier, fuel preparation, combustion engine, electric generator, local electric grid, and consumer instruments. Often it is not the gasifier, which causes trouble, but the electric system (generator, cables, insulation, switches, electric equipment) which may have a defect difficult to identify. The more complex the system, the more qualification is needed. A good operator is a real technical expert in his environment and deserves recognition.

A basic technical knowledge of the required level cannot be expected in rural areas where technical infrastructure is virtually absent, it has to be built up with patience. Very often, it is not enough to train the operator in the handling of the gasifier in a training course. In the every-day practice he must know much more, and he is not able to learn it all in just one introductory course. He needs continuous advice for an extended period until he has got the necessary experience. Therefore the introduction of any technical equipment -not only

gasifiers-has to be integrated into projects of rural development, where regular visits of the concerned villages are established. This regular backstopping was not always sufficient in the existing projects and the results were rather frequent standstills of the plants until the problem was identified and solved.

Even a high skilled operator is not motivated to care intensively for a gasifier which is obviously badly designed. Especially the skilled operator will be fascinated by a smoothly running plant and will be motivated to keep the system alive, if it is worth the effort. There is no way to deliver a badly designed equipment and hope for skill and motivation.

In common practice, the operator has a lot of responsibility, but usually very little remuneration. It is often assumed that the operation of a gasifier is something which can be done by a member of the community on a more or less voluntary basis. This is not realistic. The qualification and responsibility of the operator deserves adequate financial compensation. Principally, this is accepted by the village communities: They use to collect money for electricity supply. But electric light is not first priority. Light in the houses, radio, television - that makes life more convenient, but is a luxury that costs money. If they are in financial trouble (which happens very often), they don't pay the operator. If they don't pay, the operator is frustrated and will not do his work properly. This results in irregular electricity supply and angry reactions of the users. A conflict is likely.

8.4 Implications of non-technical issues

A resume of the above considerations is:

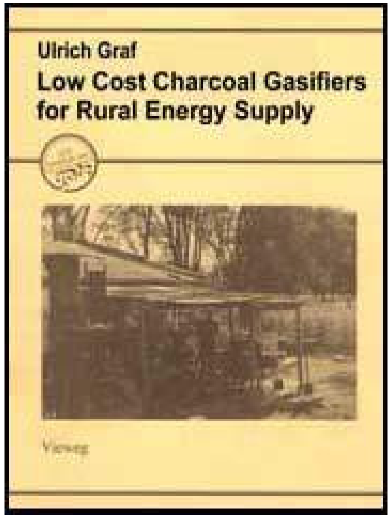
- From the view of technical performance, the ferrocement gasifier is an adequate option for the supply of mechanical or electrical energy in the 10 kW range. Waterpumping, saw mill and grain mill operation are excellent options. Rural electricity supply is the most complex task. A decision for a particular kind of application has to be based on an adequate level of technical knowledge and skill

- The ferrocement concept offers much better chances for economic viability than traditional gasifiers. But, economic viability depends on local costs of traditional energy, of materials, and of labour. This has to be calculated accordingly.

- Gasifier systems should be used for income-increasing activities Only the perspective of a higher living standard is motivating enough to deal with machinery like a gasifier-engine-systern and the complexity of fuel preparation.

- The operator must be adequately trained and paid.

- Private ownership is more reliable than community plant scheemes The traditional communal organization is -in most cases- not compatible with the sustainable management of technical systems like a gasifier



Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

9. Economics of gasifier operation

9.1 How to compare gasifier costs

It was previously said that the construction of gasifiers from ferrocement was promoted in order to enable a significant cost reduction. It is, however, not so easy to decide what "low cost" really means.

The common method to compare the investment costs of different gasifier systems is to divide the turn key equipment costs by the nominal power output in kW, resulting in "specific installation costs" (DM/kW, US $/ kW etc.). If, however, these specific installation costs are taken for comparison on an international scale, the result is often misleading. The conversion of national currencies by the conversion factors of the international financial market does not reflect the

different level of production costs in different countries. If a 10 kW gasifier can be manufactured for 6000 US $ in a German workshop, an identical equipment can probably be offered by a workshop in India at a price of 1500 $, due to lower salaries of the workers as well as to lower prices for materials. The information "this gasifier costs 600 $ per installed kW" is therefore more or less meaningless: It is only valid under a given economic situation and is not compatible on an international scale.

Therefore, informations concerning the costs of gasifiers have to be used with great caution. Whereas low-cost conventional gasifiers (metal construction) are in the range of 200-600 US $/kW, R.Reines [9] gives a figure of 46 US $/kW for a ferrocement gasifier (without engine), and the World Bank monitoring report of the AIT gasifier [l0] estimates the costs for production in Indonesia even lower (28 US$/kW). It must be seen, however, that statements concerning costs of materials and labour are very site-specific.

The costs of the ferrocement gasifier, built in Bremen, may illustrate this: The expenses for construction materials, including metal parts, were US $ 1165. The man-power involved for ferrocement work was 420 hours. With an average salary of a construction worker of $ 10 per hour, this corresponds to labour costs $ 4200. The total costs for the ferrocement gasifier in Germany are thus $ 5365 or 563 $/kW-this is 12 times the costs in Thailand!

It is exactly the same system design, which results in totally different costs per kW. In Germany a ferrocement gasifier is not much cheaper than a conventional metal gasifier.

In India, a conventional metal gasifier of 5- 10 kW shaft power costs approximately between $ 1000 and 1500.

A metal gasifier in Thailand costs about 40 % of a correspondent German plant. Referred to the standard salary, however, this plant is much more expensive than the German plant.

Table 2 shows a comparison of system costs for ferrocement gasifiers as well as for compatible metal gasifiers in three countries (Thailand, Argentina, Germany).

Table 2: Comparative costs of gasifiers Ferrocement gasifier vs. metal gasifier I US $ = 2s Baht = 1.70 DM

	Thailand	Argentina	Germany
1) Materials for ferrocement vessels ($)	120	250	400
2) External work (bunker, grate, filter bags) including labour ($)	100	150	765
(1 + 2) Total material and external labour ($)	220	400	1165
(3) Labour for ferrocement work ($)	245	900	4200
Total material and labour($)	465	1300	5365
Costs per kW, ferrocement	46	130	536
metal gasifier 10 kW ($)	2200	2200	6000
Costs per kW, metal	220	220	600

The conclusions, drawn from table 2, are:

In countries with cheap labour the ferrocement construction allows to lower gasifier costs considerably. The investment costs finally approach the range which will become attractive to the potential user, even without external subsidies. Assuming that biomass fuel for gasifiers is far cheaper than the traditional liquid fuels, an economical application of gasifiers will then become realistic.

Thus a necessary prerequisite for the further dissemination of gasifiers is met.

9.2 Case study: Comparative costs of gasifier installations in Argentina and Malaysia

The data, used for the cost comparison below, were collected recently (1991-1992) in projects of the Deutsche Gesellschaft far Technische Zusammenarbeit (GTZ). All costs are subject to changes according to the actual economic situation of the countries (this is, for example, very pronounced in Argentina). The main objective of the case studies is it to demonstrate how the final economic viability of a gasifier installation depends on varying local cost parameters. Only the most important cost parameters are taken for comparison.

To make the calculation as simple as possible, capital loans for investments are neglected. This is justified by the rather low part, represented by investment costs within the total costs of operation. Investment costs are annualized by dividing them by the system lifetime (in years). 10 years of operation are taken as reference.

The energy plant is assumed to operate 5 hours daily on 250 days per year. This

gives an annual operation time of 1250 hours.

The charcoal consumption of the gasifier system, running on 10 kW shaft power, is 10 kg per hour. This means a consumption of 12.5 tons of charcoal per year (12 500 kWh per year). Charcoal prices are 50 $/ton in Argentina and 114 $/ton in Malaysia.

The 10 kW shaft power ferrocement gasifier is manufactured locally by a team of craftsmen. After 10 years, the residual value is taken as zero.

Table 3: Annual costs of gasifier-engine systems and resulting energy costs
C = Investment costs
ACC = annualized investment costs (respectively annual costs)
(All costs in us Dollar)

	Argentina		**Malaysia**	
	C	**ACC**	**C**	**ACC**
gasifier	1300	130	1152	115
engine	2000		400	
overhaul after 5 years	1000		200	
total	3000	300	600	60
electric generator	3000	300	3000	300
charcoal		625		1425
salary operator		1800		960
total costs per year		2855		2560

total costs per year, including generator		3155		2860
Energy costs, $/kWh				
energy costs, mechanical energy		0.23		0.20
energy costs, electric energy		0.25		0.23
energy costs, grid electricity		0.50		0.08
energy costs, electric energy, gasoline operation		0.68		0.45

A second hand car engine is overhauled before installation (new pistons, bearings, some assessories). After 5 years of operation, another overhaul is necessary. After 10 years, the residual value is assumed to be zero.

Assumptions with respect to staff costs are difficult. In Argentina, the involved group was convinced that a part time job (150 $/ month) is adequate to run the gasifier, including fuel preparation (sieving of small size charcoal from nearby kilns). In Malaysia, this is considered as a full time job (80 $/month). In the case of liquid fuel operation, the assumptions are:

The same engine is used on gasoline, consuming 8 liters per hour. The gasoline price is 0.70 $/1 in Argentina and 0.48 $/1 in Malasia. Only half of the personnel costs are necessary.

The gasifier-engine-system is supposed to render mechanical energy, for example for direct propulsion of saw mill equipment (this is realized in the project in Argentina). For electricity production, approximately 300 $/ year have to be added as annual costs for the electric generator.

Discussion:

It is interesting to note that the installation costs for the gasifier are not the major part in the calculation of annual costs-this is definitely a success of the low costs of the ferrocement construction. Even the other hardware components (engine, eventually generator) are not too critical, even when considering the rather high engine costs in Argentina, compared to Malaysia. Important for the economic viability of gasifier systems are the operating costs, i.e. the costs for fuel and the operator salary. Both items are very different in both countries. An increase in the salaries for operators will have a pronounced impact on the rentability.

The difference in the resulting energy costs ($/kWh) in both countries is not too high. But, the energy costs of the gasifier system have to be compared with the energy costs of competing energy supply systems, that is grid electricity and liquid fuel operation. Rates for grid electricity in Argentina are 6 times higher than in Malaysia, and that makes a gasifier competitive in Argentina, but not viable in Malaysia, if it has to compete with grid electricity. Compared to gasoline operation, the gasifier has an economic advantage in both countries.

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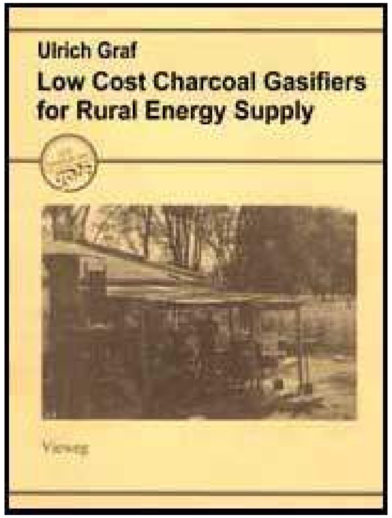
10. Concepts of future dissemination of small gasifier-engine systems



Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

10. Concepts of future dissemination of small gasifier-engine systems

10.1 Perspectives of biomass energy

For an assessment of the part which gasifier technology can play in the energy scenario of the near future, the potential of an increased energetic use of biomass has to be seen in a broader context.

Agriculture and forestry, especially that of the so-called developing countries, will increasingly be confronted with the following problems:

- On the one hand only a small amount of harvested plant material is really being used.
A far larger part of biomass remains as waste (wood cuttings, shavings, saw dust, straw, cotton stalks, coffee pulp, bagasse, rice husks and so on),

and thus poses a local disposal problem, which most of the time is "solved" by burning.

- On the other hand primary manufacturing processes need energy, which is usually provided by consuming fossil fuels. For countries with a weak economy this means an additional strain on their balance on foreign exchange payments by importing mineral oil, respectively a loss of income by fewer exports. In addition the consumption of fossil fuels always implies a strain on the atmosphere by increasing the CO2 content (introducing carbon stored in fossils into the atmosphere).

- Furthermore, developing countries have an enormous demand for biomass, needed for domestic firing processes as well as for drying processes in industry or crafts. This demand is usually covered by firing wood and charcoal from forest stands. The devastating consequences for the natural resources are well-known.

Facing these problems the tasks of agriculture and forestry have to be reconsidered. In addition to the classic demand for a sustainability of production- which is not at all realized at all times - the protection of environment and resources has to be increasingly taken into account. This requires

- protecting the still existing forest stands
- securing the sustainability of forestry by afforestation
- growing energy plantations appropriate to the according site
- efficient use of biomass by integration of waste and residues of agriculture and forestry as a source of energy and for substitution of

firewood.

By making energetic use of residues and waste material the ruthless exploitation of resources could be limited and a rational, environmentally adequate use of energy could be promoted. In this context the following technical procedures are of special interest:

(1) Gasification of residual biomass materials for generation of heat and power
(2) Substitution of firewood by other plant material
(3) Production of biocoal briquettes for use as cooking fuel and/or gasifier fuel.

10.2 The actual limits of gasification technologies

In this report, a low cost charcoal gasifier for power applications in the range of 2 - 10 kW is presented and discussed. This gasifier seems to be appropriate for applications in rural areas of developing countries. But, this does not mean that gasification technology is already available to an extent that could contribute significantly to solve the problems listed above. The fact that, at the given state of the art, only charcoal can be recommended as fuel for small gasifiers (and, as well, that the use of charcoal cannot be recommended for large gasifier units!) indicates the actual limits of this technology. Charcoal production is bound (or should be bound) to forest management, and charcoal gasifiers should be used within close reach of forest areas. Even within this limitation, there is enough room for a substantial number of sites for gasifier units.

With respect to the regional energy consumption patterns however, the impact of small gasifier-engine-systems is rather marginal. If charcoal production is established, the major part of it will be consumed as cooking fuel. The additional demand for gasifier fuel is limited by site-specific considerations (is a gasifier suitable for a certain application), by economic considerations (is it significantly cheaper than competing energy supply systems) and by the still important aspect of acceptance of a reduced operational comfort.

Considering all these limits, an uncontrollable dissemination of small gasifier plants to an extent that results in an additional stress on natural resources appears not to be realistic.

An aspect which is not yet sufficiently studied is the use of commercially low-value charcoal for gasification: Observations in Argentina as well as in Malaysia have shown that a certain percentage of the charcoal, produced in local kilns, is of a physical dimension (particle size 1-2 cm) which is not desired by domestic consumers but well suited for gasifier application. A classification of kiln charcoal into "cooking fuel" and "gasifier fuel" may result in an increased efficiency of charcoal use without much additional demand for wood to be carbonized.

But certainly, the gasification of unused biomass residues, especially from agriculture, for the purpose of gaining mechanical and electrical energy in rural areas could considerably enlarge the contribution of biomass energy within a national energy scenario. Using uncharred biomass in gasifiers is easier when the biomass fuel is already available in a shape and size which demand no further treatment. This is for instance the case with nutshells, corn cobs, rice husks, saw dust and wood shavings.

Especially rice husks and saw dust/wood shavings are raw materials which are widely spread but hardly used. Gasifiers for rice husks have been intensively investigated in South East Asia and India for many years. Gasifiers for sawdust are practically nonexistent at the moment, even though the technology was still being employed in Germany a few years ago. In many countries of the Third World, however, there is a high demand in mechanical and electrical power for small saw-mills (10-20 kW power output), which could be met by stationary gasifiers (application for driving machines as well as power supply for small settlements). But, all existing gasifiers for agricultural and forstry residues share the basic disadvantage of producing a tar loaden gas, which has to be cleaned in a special gas cleaning train before entering the engine. This process is not always effective and, in most cases, results in condensates which require a final treatment before being released to a drainage system. This final treatment is neglected in practice. The design of gasifiers for uncharred biomass, producing a ,,tar free gas" (at least in defined quality) within the thermochemical process (and not by a cleaning process) is a demand which is not yet solved.

Gasifiers for heat applications are technically much less sophisticated, as tar loaden gases can be burnt with excess air in the burner. Obtaining process heat for industrial drying plants by means of gasification systems could contribute considerably to the protection of natural resources. The efficiency of gas producers is about twice as high as that of a simple furnace. The potential savings in firewood have to be estimated to be rather high (e.g. for large tea-drying plants: several thousand tons of wood per year and plant).

Co-generation of heat and power, based on biomass fuels, is a technology of increasing importance for industrial applications.

10.3 Substitution of firewood by other biomasses

Fuel for gasifiers and fuel for domestic cooking will always compete to a certain extent. The search for alternative cooking fuels will play an important part in the future, and a basically available technology is the production of briquetted fuel from residues/ wastes in agriculture and forestry. An alternative to traditional charcoal production could be the production of big-coke briquettes from especially common agricultural waste, using methods of an "intermediate technology". A classification of biomass or big-coke briquettes with respect to their suitability to domestic firing, but also to gas production by means of gasifiers is needed to form a basis for further decisions.

The problems are not so much in the technical as rather in the economical and political field. Fuel prices, for example the price of biocoal briquettes, have to be seen as political prices. If a relevant substitution of fossil fuels and fire wood by briquettes is acknowledged as an important goal, a subsidized price for briquettes may be worth thinking about.

A risk of the increased offer of commercial fuels, derived from a variety of biomass residues, is possibly a reduced availability of "free" fuel for the poorest of the poor.

10.4 Framework for establishing gasification technologies

Information policy

Not every detail of the gasifier technology has yet been solved, and the rather convincing approach of the ferrocement gasifier as a cheap and reliable equipment

in the power range of around 1 0 kW is just a first step. But, if the advantages of big-energy in a future energy supply scenario are taken seriously, it just depends on the decision to do it.

This decision has to be based on a broad public support. Gasification technologies are rather unknown, compared to other renewable energies like photovoltaics, wind energy, and even biogas plants. Quite a lot of prejudices and misinterpretations appear when people are confronted with a technology which is based on biomass consumption- that is, at least in industrialized countries closely connected with overexploitation of forest reserves, which is definitely not the meaning of "sustainable biomass manage meet". A correct and comprehensive information about the meaning of "energetic use of biomass" in the context of a sustainable biomass management is necessary to create a general acceptance.

Governmental backstopping

A new technology - and for the user, a gasifier is a new technology - needs some support to be integrated in a commercially oriented economy. Even under the improved starting conditions which an economically viable ferrocement gasifier may have compared to its more expensive predecessors, this technology will have to compete with more familiar and established equipment and even face an unfair competition with subsidized prices for liquid fuels.

Any dissemination of gasifier technology must therefore be based on an energy policy which encourages the use of new and renewable energies. India and Thailand belong to the few countries which already go in this direction:

"The Thai government has adopted a policy of utilizing locally available energy sources in order to reduce the amounts of imported energy. (...) For biomass this policy calls for a more efficient utilization of wood and charcoal and using more crop residues such as rice husk and bagasse"[7].

The Thai government encourages the adoption of nonconventional energy technologies through soft loans and tax exemptions for manufacturers of technically reliable gasification systems. An important demand is seen in rural electrification: 6% of the 50000 villages of Thailand are not connected to the grid, but is is estimated that 20 % of the rural population needs decentralized energy supply due to the fact that even existing electric grids can not supply all households and the numerous demands in the fields (e.g. irrigation pumps). Furthermore, mechanical energy is needed for rice milling, paddy threshing, milling of corn, cutting of wood in sawmills, crushing and squeezing of sugar cane [7].

The most important power demand is seen in the range of 5-10 kW.

According to Jain [6], the situation in India is very similar: "Changes in international oil scenario and increased import budgets for petroleum products etc. resulted in specific commitment being made to renewable sources at the national policy making level. This has been reflected through establishment of a separate department (Department of Nonconventional Energy Sources - DNES) within the Ministry of Energy at the Government of India level and establishment of state nodal agencies to propagate increased use of renewable sources in almost all states".

In the context of an overall national strategy aimed at reducing dependence on imports of petroleum products, power generation by gasifier systems is seen as a major focus. A need is defined for mechanical shaft power applications with major emphasis on irrigation systems, on electricity generation for rural industries, farms and institutions, and in direct heat applications for rural industries as well as for institutional cooking. The relevant power range, especially for millions (!) of irrigation water pumps, is 3.5-7.5 kW. For rural electrification and thermal applications, 10 kW electrical output respectively 50 kW thermal output is the adequate size.

Jain gives an interesting assessment of the quantitative impact of a large scale application of gasifier units for irrigation pumping in India:

- 1% of the current national firewood consumption can be adequate for producer gas based operation of 240000 pump sets (3.5 kW each) or for electrification of 60 000 villages.

- A farmer could just use 3 to 4 % of his land for fast growing tree species to support his entire irrigation needs perennially. Alternatively, he could use up to 25% of the residues produced and meet his irrigation needs through small scale producer gas systems.

- Typical energy plantation yields can be anywhere between 10 tons and 60 tons (wet weight) per hectare and year and the country has a minimum of 62 million hectar of wasteland, a significant fraction of which could be used for energy plantations."

According to Jain, even hundreds of thousands of small scale gasifier systems would only have a marginal impact on the environmental balance. Nevertheless, it is desirable to focus dissemination programmes on biomass surplus areas and to ensure the sustainable production of feedstock, either in terms of residues or through fast growing tree species.

It must be seen, however, that despite all governmental support the dissemination of gasifier technologies in Thailand and India has not yet been as successful as expected. Obviously, the gasifier technology is still not as attractive to the potential user, compared to the conventional diesel or gasoline system.

Stimulating large scale applications of gasifier systems

The next steps should be the integration of demonstrative plants in project activities which present a convincing model for"biomass management". Having in mind that gasifier technology can contribute to environmental protection, especially with respect to the global concern about CO2 emissions, some isolated demonstration projects are definitively not enough. A large scale application however will depend on politic decisions and economic considerations and will require the following steps to be taken:

(1) Effective use of biomass resources for energetic purposes has to be recognized as part of a policy of increased use of regenerative energies with the aim to reduce expenses for petroleum products, to reduce CO2 emissions and to increase the living standard in underprivileged areas. Biomass energy has to be considered as an important contribution to the efficient and sustainable management of biomass resources.

(2) Local manufacturing of gasifier systems should be encouraged by investment subsidies and tax exemptions.

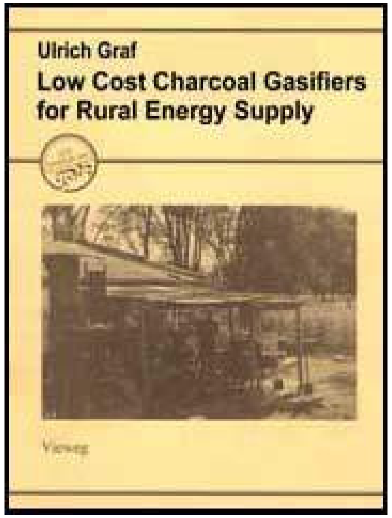
(3) The energy demand and the respective demand and offer of biomass fuels has to be balanced. This will require careful selection of sites for installation in the early phase of a dissemination programme. In the long run, a commercialization of gasifier fuels by fabrication of biocoal briquettes from agricultural residues is one of the most important requirements for large scale introduction.

(4) With respect to application, two different strategies should be pursued:

a) Commercial application for irrigation water pumping, mechanical and electric power generation for cottage industries, gas generation for institutional cooking. A financial package of soft loans, tax reduction etc. may be necessary to compensate competitive advantages of traditional energy supply systems.

b) For underprivileged areas and communities, fully subsidized electricity supply can be seen as a part of a policy of compensation of social deficits. The involvement of gasification technology offers a step to rural autonomy and creation of additional jobs on the countryside. A continuous technical assistance will be necessary until the technological knowledge and experience has settled. Energy provision alone, however, will not be sufficient for any progress.

(5) The aspect of fuel supply for gasifiers should be seen in a context with the fuel supply for cooking purposes. In the long run, firewood and charcoal from forest reserves should, to a large extent be replaced by fuels derived from agricultural and forestry residues. The cultivation of fast growing energy plants on areas, not needed for agriculture, may be a necessary contribution to the energy potential.



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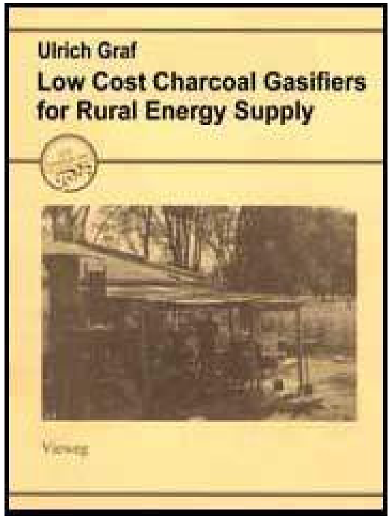

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Foreword

Supported by the German Federal Ministry for Research and Technology (BMFT), the GTZ (Division 415-Energy-Conservation of Resources and the Environment) has implemented a back-up programme to complement the technical development of small gasifiers.

This programme focussed on elaborating the non-technical criteria which need to be met for the sustainable dissemination of small gasifiers in developing countries. It cooperated closely with the research laboratory for energy conservation and environmental protection systems (FLEUS) at the University of Bremen, which was commissioned by the BMFT with the technical development of small gasifiers.

This publication presents the essential results and findings obtained in the two projects, and arising in the process of international dialogue. The potential for dissemination of this technology is limited. The publication demonstrates to interested laypersons and experts the conditions and applications under which small charcoal gasifiers can be one option for development within a range of simple energy technologies, some much more extensively tried and tested.

Eschborn, 20 August 1993
Division 415-Energy-Conservation of Resources and the Environment

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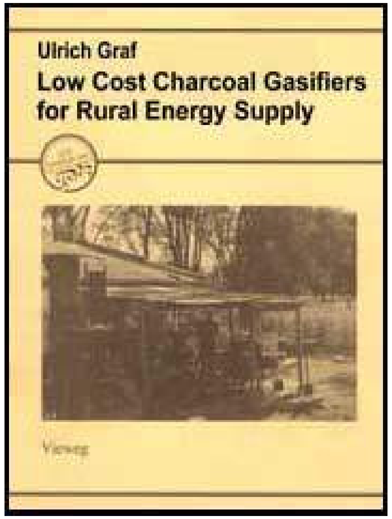

1. What? Gasifiers?

Environmental concerns, especially with respect to a rising content of CO_2 in the

atmosphere, make the extensive use of fossil fuels in the future more and more suspect. But what is the alternative? Perhaps liquid hydrogen, produced with the help of photovoltaics in desert areas - but this is still speculative, like the complete energy scenario of the future is. What can be done in short terms to at least limit the increasing consumption of fossil fuels?

Energetic use of biomass is one of the options which are dicussed under the headline "renewable sources of energy". There is one basic advantage of big-energy, compared to fossil energy:

If fossil fuels are burnt (and heat production by combustion is the first step in nearly all technically relevant energy conversion processes), the carbon, stored in the coal or oil, reacts with the oxigen of the air and forms carbon dioxide. This is the reason for the steadily increasing CO2 content of the atmosphere, together with the reduction of CO2 sinks' represented by tropical rain forests. If harvested plant material is burnt, the combustion reaction is the same. But, the storage time of the involved carbon is much shorter. The combustion is the reverse process of the photosynthesis: The amount of carbon, assimilated during the growth period of the plant, is released as CO2. If the plant is replanted, the carbon cycle is closed. Thus the combustion of plants, if handled in a sustainable way, is CO2-neutral (apart from eventual CO2 production by fertilizer production or harvesting machinery etc.).

It is not increased consumption of wood which is meant by energetic use of biomass. It is the more effective use of plant materials by integration of waste products of agriculture and forestry in the product line. Bio-Energy can be the result of anerobic digestion (in biogas plants), it can be represented by plant oils,

alcohols, and so on. Another technology of energetic use of biomass is gasification.

Gasification means thermochemical conversion of solid plant material into gaseous components. In a few phrases, a gasifier works as follows: Air is sucked through an already ignited charcoal bed. In a first reaction layer, the oxygen in the air is reacting with the hot charcoal, resulting in carbon dioxide (the typical combustion gas). The carbon dioxide, together with the water vapour of the fuel, is reacting with the adjacent hot charcoal layer, resulting in a mixture of gases, which contains around 28% of carbon monoxide, some 8% of hydrogen, a few percent of carbon dioxide, and around 58 % of nitrogen, the latter being an inert component of the air flow into the gasifier. Only about 36% volume of the gas mixture are inflammable components, and the heating value of the mixture (approx. 4000 - 5000 kJ/Nm³, Nm³ = norm cubic meter) is not very high. But, mixed with air, the gas can be ignited by the spark plug of a standard gasoline engine, serving as an engine fuel. Theoretically, the engine could run with 30 % power loss compared to gasoline operation, but in practice the losses are higher. As a rule of thumb, 5 kW shaft power can be expected per liter engine volume at 2500 revolutions, if producer gas (that's the name of it) is applied.

The basic chemical reactions of gasification take place in a charcoal bed. This does not mean that only charcoal can be gasified. If wood or any other dry plant matter is filled into the tank of a gasifier, the material is automatically dried and pyrolized due to the high temperatures of the combustion zone, before entering this zone. For more details, extensive literature is available [1,2].

Theoretically, any plant material with a moisture content of 5-30 % can be

gasified, as the basic composition of carbon, hydrogen and oxigen is almost the same (on dry, ash free basis). That means that agricultural wastes like rice husks, straw, nut shells, and forestry residues Like branches, trunks, bark and so on are all potential gasifier fuels-but only theoretically. The physical properties of the fuel as well as the ash content are aspects which define if it is worth the effort to gasify or not.

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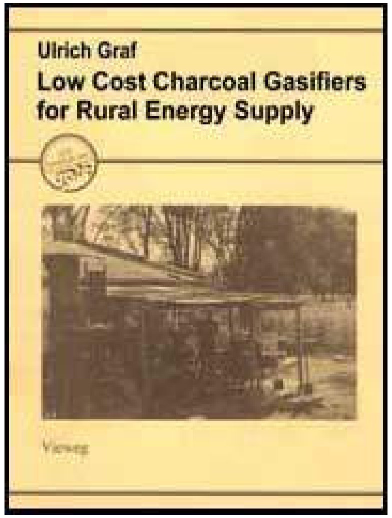

2. Gasification in recent history

Gasification is not a new technology. Germany is a country with extensive historical knowledge in practical operation of gasifier powered vehicles, and a lot of literature is available from that time, which is not so long ago: It was during the Second World War, when about 350000 vehicles in Germany were running on gas. But is was not a free decision of the vehicle owners to fix a gasifier on the back of his lorry, tractor, or private car: It was ordered by the military administration in order to save fuel for the war machinery. Virtually every detail of the application of gasifiers on vehicles was regulated by the Special Department for Gas Generators (Zentralstelle fur Generatoren): The type of gasifier, the type of fuel, the fuel supply per month. Great efforts were made to concentrate gasifier manufacturing on a few, standardized types, designed for the available types of fuel (wood, charcoal, anthracite, brown coal, hard coal and peat).

Remarkable is the way of fuel standardisation: Narrow specifications were introduced to standardize particle size, content of ash, sulphur, moisture, tar and volatile components, calorific value and specific weight. Of course, the high requirements of standardization could not be met by small scale fuel production. The preparation of solid fuels was under the responsibility of a special industrial branch, directly under the command of the Central Department for Gas Generators.

So, an extremely detailed, centrally organized administrative structure was necessary to realize a substantial conversion (in the order of 25 %) from liquid fuel to solid fuels.

The German experience with gasifiers was definitely not a decentralized, environmentally appropriate technology. It was an emergency technology, which disappeared a few years after the war, when liquid fuels were available again.

The renaissance of gasifiers began in the late seventies. It was the first "oil crisis" which triggered research and development in gasification, especially in those developing countries depending on oil imports. Facing the abundance of agricultural and forestry wastes in these countries, it was a logical attitude to focus on gasification of these low-value resources. But here begins the trouble: Theoretically-but only theoretically-all these plant residues can be gasified. But the extensive experience with gasifiers from World War II was acquired with wood- and coal gasifiers, and this is something completely different. The underestimation of the technical problems which arise when matter like rice husks, straw, saw dust, coconut husks, cotton stalks and so on are to be gasified, resulted in a number of insufficient design proposals and finally in a disappointment of promotors and users.

The fact that the oil prizes did not rise in the anticipated way, but to the contrary remained at low level for nearly a decade, gave the rest to gasifier enthusiasts. The job was just too tricky and not worth the effort.

Meanwhile, the interest in gasification has re-adjusted. It is not seen as a universally applicable option for energy supply, but as a component within the

range of available "regenerative energies". It is a valuable supplement to photovoltaic systems, solar collectors, small hydropower systems, wind energy converters, and biogas plants. According to site specific conditions it has to be decided if an energy supply based on renewable energies is technically and economically viable or not, and whether this might be gasification or anything else. An advantage of gasifier systems is it that standard internal combustion engines (Diesel and Otto cycle) for a wide power range (1-100 kW shaft power) can be used for gas operation, and that the investment costs and life cycle costs for a gasifier are much lower than the respective costs for all other regenerative energy converters in the kW-range. A disadvantage is the necessary effort for fuel preparation and the resulting operational costs, which can vary considerably and do in fact define the economic viability of a gasifier-engine-systems.

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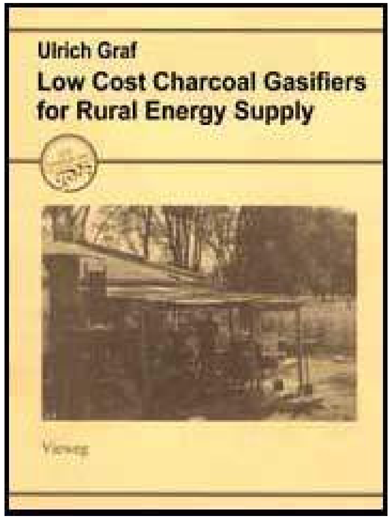

3. Small gasifier-engine systems for rural energy supply in developing countries

Rural areas in developing countries are commonly characterized by disperse population and a lack of infrastructure. Especially the electric grid, a symbol for industrialization and high living standard, is missing and is extremely unlikely to be installed even in medium terms of energy planning due to the large distances and the low level of industrialization. On the other hand, energy supply is a basic condition for improved living conditions and increased productivity.

Especially important is the energy supply in agriculture, for example for irrigation pumps and the various machinery for post-harvesting, including grain mills. Small scale processing machinery (small saw mills, metal workshops) are another option, and last not least it is electricity for domestic use (light, radio, television). All that can be covered by "gensets" (the combination of a combustion engine and an electric generator) of 3-20 HP (2-15 kW) shaft power, and this is exactly the power range for"small gasifier-engine-systems". Such gasifier systems do not

consume excessive amounts of fuel: If firewood is available at sufficient amounts, a gasifier for village energy supply should not present a problem of fuel shortage. Even the use of charcoal as fuel is acceptable for small gasifiers. Of course, energy losses are a consequence of charcoal production. But, on the other hand, charcoal is an excellent gasifier fuel, it avoids tar formation in the gasification process, and the sizing of the fuel particles is much easier than the respective cutting of wood. At the present state of the art, the use of charcoal as fuel is highly recommendable, if gasifier-engine-systems around or below 10 kW shaftpower are to be applied.

Two International Conferences on Producer Gas, held 1982 in Sri Lanka and 1985 in Indonesia focussed on this topic, and a substantial amount of research and development was presented at these occasions. Then, gradually, the interest faded away. That happened when the state of the art was apparently not too far away from a level, sufficient to render technically viable results. That was the point when a joint project of the

German Ministry for Research and Development (BMFT), the German Agency for Technical Cooperation (GTZ) and the University of Bremen started. The aim of the project CHAR (CHARcoal gasifier), carried out by the "Forschungslabor fr Energie- und Umweltschutzsysteme (FLEUS)" at the University of Bremen, was the development of a reliable and cheap charcoal gasifier in the power range of 2-10 kW, based on an evaluation of the existing international experience with such systems. Parallel to this project, GTZ ordered a set of studies concerning non-technical aspects of gasifier application, such as problems with handling and maintenance of gasifiers under field conditions as well as reports about existing dissemination programmes in selected countries (see [3 - 8]).

As the project started at a time when it was already obvious that the existing gasifier systems did not meet the expectations, the search for reasons for the limited success was the first step to define further research activities.

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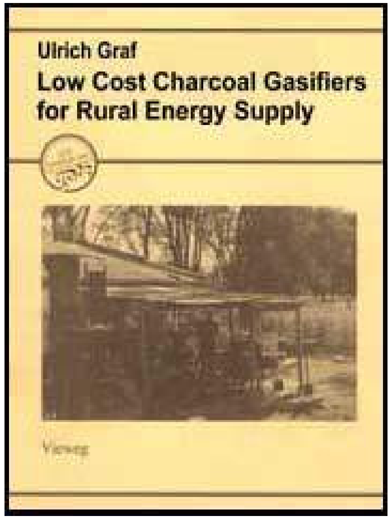

Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

4. The trouble with ''field applications''

4.1 Weak points of gasifier-engine-systems

It became obvious in the late eighties that despite the lively interest in the gasifier technology during the past 10 years no "dissemination" worthwhile mentioning had taken place. The dominant argument to explain this was the claimed

"technical immaturity" of the systems. This requires some comments.

It is typical for gasifiers employed in developing countries over the last years that these systems had mainly been developed by research institutions and universities. These plants (all of them prototypes) showed technical shortcomings as soon as they were tested under the rough conditions of "field application". In the end their failure consisted of a sum of mistakes made in details, which only came to light when the favourable conditions of lab application (defined and constant fuel quality, good possibilities for repair and optimization, qualified and motivated operators) were missing: Bad bunker flow of insufficiently prepared fuel, unoptimized container geometry, fast wear of parts subjected to varying temperature, wear of scalings, problems of corrosion, insufficient gas cleaning were wide-spread defects [3].

On the basis of subsequent documentation quite often it can also be reconstructed that grave mistakes have been made in the adaptation between gasifier output and engine size (usually the cylinder volume of the engine was chosen too small, thus preventing the gasifier from reaching the necessary operating temperature). Often there also existed wrong ideas about the application purposes, to which gasifiers might generally be suited or unsuited.

More will be said on the technical aspects later in this paper. First, however, another approach is chosen. The most commonly used argument of the allegedly existing technical "immaturity" of those gasifiers available certainly often holds true for some wellknown cases, but it can no longer be accepted as the sole reason for the hitherto limited dissemination. Technical problems are almost always solvable, once they have been recognized. Meanwhile, knowledge about

gasifiers should be sufficient to realize good technical performance. But still the reputation of this technology is not too good.

4.2 The problem of ''acceptance''

If a farmer in a developing country prefers other energy technologies to gasifiers, even though this preference cannot be reasonably explained from a technical point of view, one has to ask for the non-technical reasons. In such cases "acceptance" is always quoted- a mysterious term which circumscribes that the user does not agree to this new technology. In reality technical and non-technical reasons for a lack of acceptance can seldom be clearly separated; the one often stems from the other.

There is one trivial fact which can explain low acceptance of gasifier systems: Nothing is as convenient as an electrical socket. A household connected to the public electrical grid is already something self-understood for inhabitants of towns; for the rural population, too, it symbolizes the modern way of life in a nut-shell. Sockets in the house-this means unlimited access to energy at all times, be it for cooking, washing, ironing, providing light, or watching television.

The typical consumer-and this not only holds true in industrial nations, but in developing countries as well-does not want to take care of any technical service of his energy supply. The public energy supply of industrial nations meets this need to a very high degree: it provides energy at high reliability and acceptable costs. And just that is, what the housewife in a developing country wishes for as well. That is why all decentralized systems, and especially those based on renewable energy, have not much chance to be loved.

But: As attractive as the public electrical grid may be, for many people it will just remain a dream. It is the population of rural areas in the developing world which has to be regarded as the foremost target group for the employment of regenerative energy sources. In general, this target group has no access to the public grid, and no realistic chance ever to gain it: A low population density and a low economic significance of those concerned promise little profit to enterprises selling electricity, should they extend their supply lines to every village. And yet: if you promise people in rural areas a better life, they will, among other things, expect electricity.

Only if access to grid electricity is unrealistic, it will be sensible to ask which energy conversion system the user might prefer as an alternative. The answer can be found in the afore-said: the operating comfort should come as close to the socket as possible. Compared to other alternatives a gasifier will not have the best of chances.

The traditional alternative to the mains is an energy supply by means of local engine-generator-sets. Though an engine-driven generator supplies electricity, it is not the same as being connected to the grid: Fuel has to be bought continuously, and one always lives with the risk of having an engine failure, but not the money for repairs. In brief: one has to take care of it permanently. On top of that, due to bad road conditions and a virtually non-existing infrastructure in the rural areas of developing countries, liquid fuel is very expensive in relation to the low income of the consumers.

Apart from diesel or gasoline engines, there are not many alternatives available. Liquid fuels on biomass basis might present a future option to replace diesel, if the

question of rentability could be solved.

With regard to operating comfort, a photovoltaic plant is very attractive, and as far as household illumination and small-scale consumption is concerned, photovoltaics already represent an acceptable solution for those users who are financially well-off. If, however, mechanical or electrical energy is needed for working machinery (water pumps, grain mills, machines for carpentry, and the like) that lie in the power range from 2 kW up, photovoltaics are excluded for reasons of costs.

Small hydro power and biogas plants are other site-specific options for decentralized energy supply.

A gasifier-engine-system using solid fuel, as perfect as it may be, always requires more extensive operating care than an engine run on liquid fuel. But: if not quite love, at least acceptance might arise, if a gasifier offered considerable cost advantage. As the user in developing countries finds himself chronically in a situation of permanent financial difficulties, the term "acceptance" will simply be reduced to his insight in the necessity of saving money.

From this we may derive the kind of demands which have to be put to gasifiers in order to make them acceptable. If we assume that gasifier technology has matured enough to let its operation appear not more difficult than that of other, comparable energy technologies, the potential user will have the following requests:

(1) The operation of a gasifier should have considerable cost advantages

when compared to available, competitive technologies (e.g. Iiquid fuel engines).

(2) It should be guaranteed that the plant fulfills the technical requirements of the application it is intended for (or in other words: it has to be clear what a gasifier is suited for, what not).

(3) The effort for preparing the fuel, operating the system and maintaining it should be kept as low as possible.

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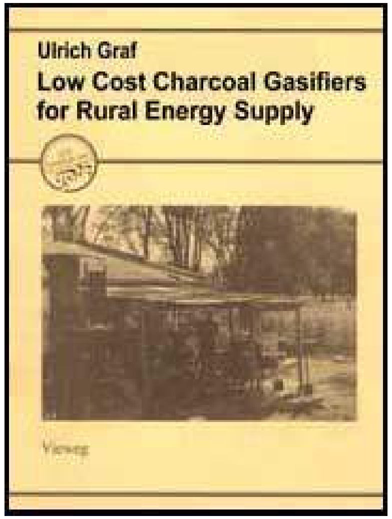


Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

5. Lowering plant costs by ferrocement construction

5.1 What makes a gasifier expensive?

For a small farmer in a developing country, the investment risk of installing a gasifier is normally too high when compared to the expected savings. Apart from the mere investment costs, a gasifier causes operational costs which are mainly dependent on the fuel price: Even if the basic material is free, the general costs of preparing the raw fuel in a way that makes it suitable for gasifiers have to be taken into account. Thus it is even more important that the mere investment costs for the gasifier remain as low as possible.

The system costs for a gasifier depend on two aspects: The simplicity or complexity of the design, but also to a considerable extent on the materials used. Recent considerations have shown that the latter offers the key to an economic success.

The core of a gas generator is the reaction chamber, in which the thermochemical conversion of solid fuel into usable gas takes place. In the combustion zone, temperatures of around 1200 °C are reached, and in the adjacent reduction zone temperatures between 850 and 650 °C have to be expected. These combustion and reduction zones have to be surrounded by high-temperature resistant vessel walls, that is, special steels or (most commonly) fire-resistant refractory bricks.

The rest of a gasifier unit mainly consists of vessels and pipes, that is, containers for fuel and ashes, as well as containers and pipes for gas cleaning and cooling. These vessels are traditionally made of metal. Their manufacture requires sheet forming tools and welding equipment, drilling machines, thread cutting equipment and so on, as well as skilled workshop personnel. The resulting price is oriented

on the regionally common costs for labour at a metal shop. Therefore a metal system is always relatively expensive. Even the fact that in India for instance, manufacturing can be done for a fraction of the costs (converted into DM) that are involved in Germany, does not change the situation that the average income of an Indian farmer is also only a fraction of the income of his German counterpart. Thus, specific investment costs of 200 DM per installed kW for a gasifier in India may correspond to 2000 DM/kW in Germany-both values are too high for economic attractiveness.

Within the last few years only one breakthrough in manufacturing costs for gasifiers has been outlined, and this is based on turning one's back to metal constructions. As the vessels and pipes do not have to withstand any heavy mechanical strain, metal constructions-derived from the manufacture of heating systems-do not constitute a necessity. It has long been known that gasifiers can be built from brick work, but this has often posed a problem, when trying to achieve gastightness. At the AIT Bangkok Robert Reines [9] took another road when adopting the ferrocement technique, known from water tank construction and ship building technology. With this technique (which mainly implies the construction of wire armatures and wire-mesh forms which are then plastered with mortar, see fig. 5-9) it is possible to produce cylinders, tubes, lids, and so on, in any desired shape. The costs for material are lowered drastically, as merely wire, wiremesh, cement, and sand are needed. The problem of temperature strain is solved in two ways: the reaction zone is fenced in by a heat-resistant brick cylinder, and a general cooling tub surrounds all vessels.

Based on the impressive presentation of the AIT ferrocement gasifier, given by Robert Reines on the First International Workshop on Small Scale Producer Gas

Systems in Bremen, 1989, the project CHAR focussed its activities on this approach. The steps of work were

- to gather experience with the technique of ferrocement construction

- to evaluate the system costs under varying local conditions -to test the performance of the ferrocement gasifier as well as the performance of competitive designs -to develop criteria and recommendations for practical application.

5.2 The construction of a ferrocement gasifier

A typical working schedule is the following:

First week

Final check of available materials and tools, completion.

Wiring of inner cylinders, top attachments, ash ports, covers. Ordering of metal parts, to be prepared in the workshop (fuel bunker, grid, shroud). Preparation and leveling of the platform for the gasifier.

Second week

Plastering of inner cylinders and attachments. Wiring of outer tank, plastering of outer tank. Construction of refractory cylinder and refractory disc. Curing of plastered parts. Begin of assembly of the inner cylinders in the cooling tank.

Third week

Completion of final assembly, water leak proofing.

Installation of the grate and the metal shroud Installation of the engine with gas-air-mixer and gas inlet manifold adapter.

First tests of gas production, run by an electric fan.

Installation of fabric filter bags, first test runs with engine suction.

Last modifications on the gasifier-engine-genset.

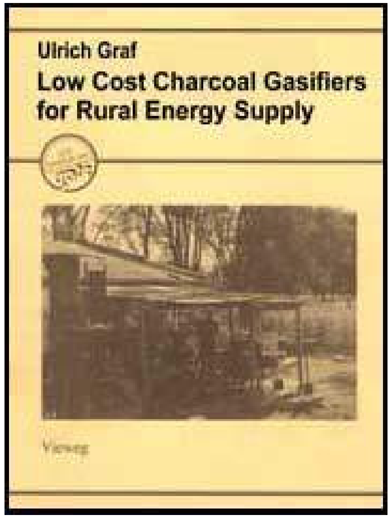
Fourth week

Commissioning of the gasifier-engine-genset. Test runs with engine without load.

Demonstration of alternative starting procedures:

- **by suction fan**
- **by suction manifold from engine**
- **by stove mode**

Demonstration to personnel in optimum operation and maintenance of the ferrocement gasifer.



Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

6. Technical performance of the ferrocement gasifier

6.1 Design details

For a better understanding of the specific advantages of the ferrocement design, it is useful to distinguish criteria of constructive design (which can be applied in a metal construction as well) from material-specific criteria (which are typical for the application of ferrocement). It will become obvious that the ferrocement charcoal gasifier, as realized in its present form, is possibly just the first step in a different way of building gasifiers.

The gasifier of Robert Reines is a down draft gasifier with a straight cylindrical reaction zone-this is common to all conventional small charcoal gasifiers. Furthermore, it is of an ,,open core" type. That means, primary air for the reaction

zone is not entering through nozzles (wall nozzles, central nozzle), but has a more or less unlimited access to the combustion zone. The open core principle has been applied so far mainly in rice husk gasifiers in down draft operation, where the flow of primary air is uniform over the complete cross section of the fuel bed. This is slightly different in the ferrocement charcoal gasifier discussed here, where the fuel bunker, closed by a top cover in a water seal, is sitting on the combustion zone. The primary air enters through a circular slit between cylinder wall and bunker rim (see fig.9). The application of this open core principle has an important impact on the technical reliability of the gasifier: The problem of disturbed bunker flow, often reported from nozzle gasifiers, is definitely reduced, as no nozzles disturb the downward flow of the fuel column. In addition to this, the uniform temperature distribution over the cross section of the combustion zone improves the flow characteristics. As an additional effect, no nozzles can melt or flake, an effect which requires subsequent repair work in nozzle gasifiers.

The reactor cylinder in the gasifier is easily accessible by removing the bunker. This is an advantage to the refractory lining in closed metal vessels of most conventional gasifiers as it is easier to replace the refractory cylinder by another one of different diameter in order to adapt it to the engine size. In order to avoid thermal ruptures of the refractory walls, the cylinder is preferably made of three rings of three blocks each. The thermal insulation to the outer wall is made of compacted rice husk ash. According to Reines, the ash begins to melt near the refractory cylinder surface and thus seals the slits between the bricks.

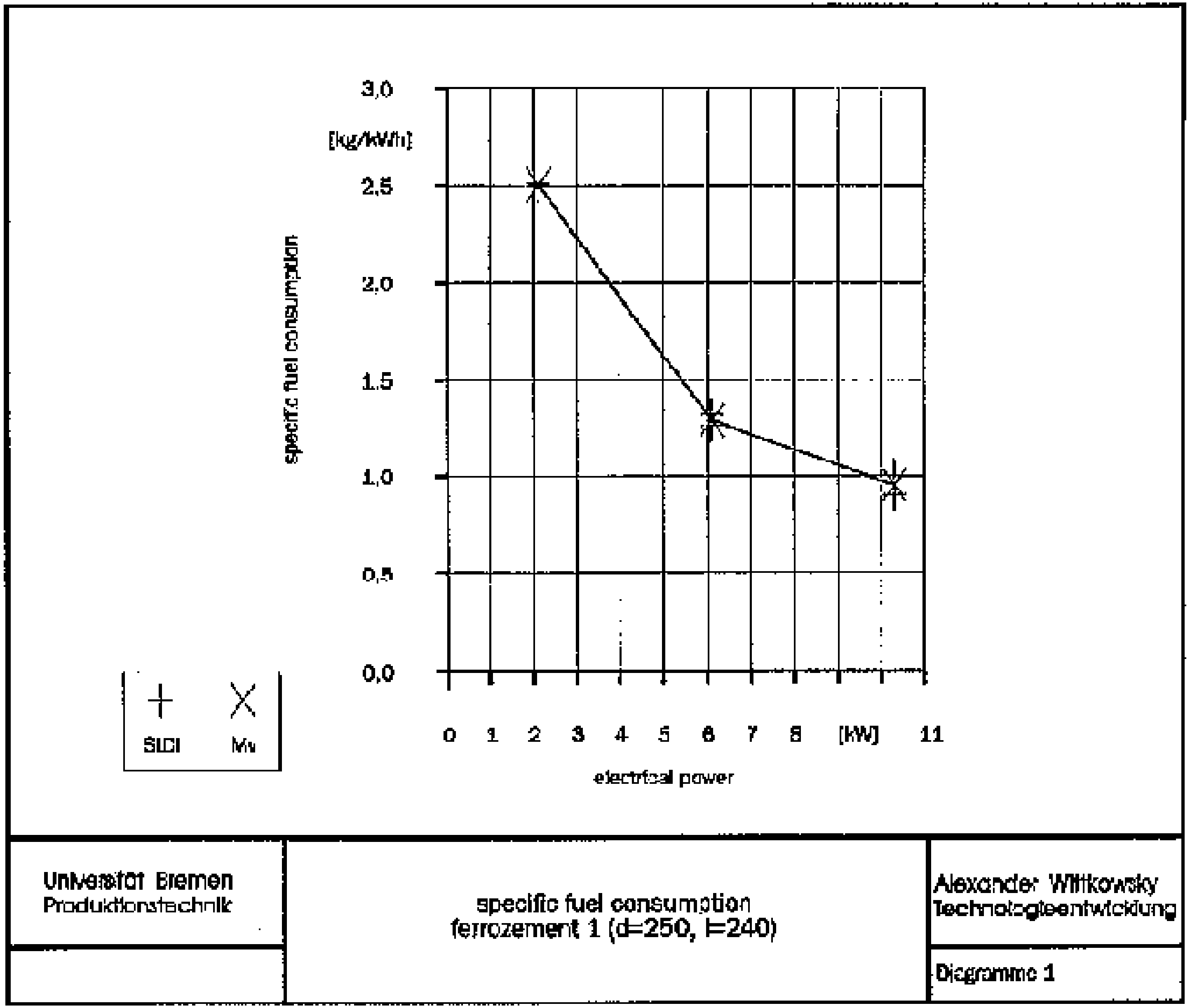
Table 1: Typical performance data of the ferroment gasifier (Mean values, ar = as received) Reaction cylinder: 300 mm diameter

	unity	amount
fuel input:		
charcoal		
higher heating value, ar	kJ/kg	31387
fuel consumption for starting period, ar	kg	6
specific fuel consumption under load (10 kW)	kg/kWh	0.97
Gas components:		
CO	% vol	25.3
CO2	% vol	3.8
H2	% vol	6.7
gas flow	Nm^3/h	60
gas heating value	kJ/Nm^3	3924
gasifier conversion efficiency	0.74	
engine/generator set:		
engine volume	liter	2.0
engine speed	rpm	2500
volumetric efficiency		0.71
engine/generator efficiency		0.162
power output, electrical	kW	10.5
total conversion efficiency (electrical power vs. Fuel heat content)		0.12

The configuration of the reaction zone of the Reines gasifier is not determined by the application of ferrocement as main building material; it can be done in the same way in a metal gasifier [12]. It has been said already that the open core principle is not completely new in gasifier construction. It is, however, not common in small charcoal gasifiers, and it is not necessarily guaranteed that it is effective in that case. Therefore, as a first step it had to be tested wether this design was as good-or even better-than a nozzle gasifier in terms of effective conversion of solid fuel to combustible gas.

6.2 Performance data

In table 1, data are listed which were measured at the operation of a standardized gasifier in ferrocement construction, designed for a power range of 2-10 kW. These data are derived from test series, carried out in the laboratory of FLEUS (Bremen University). More detailled data sets can be derived from the project report for BMFT [12].

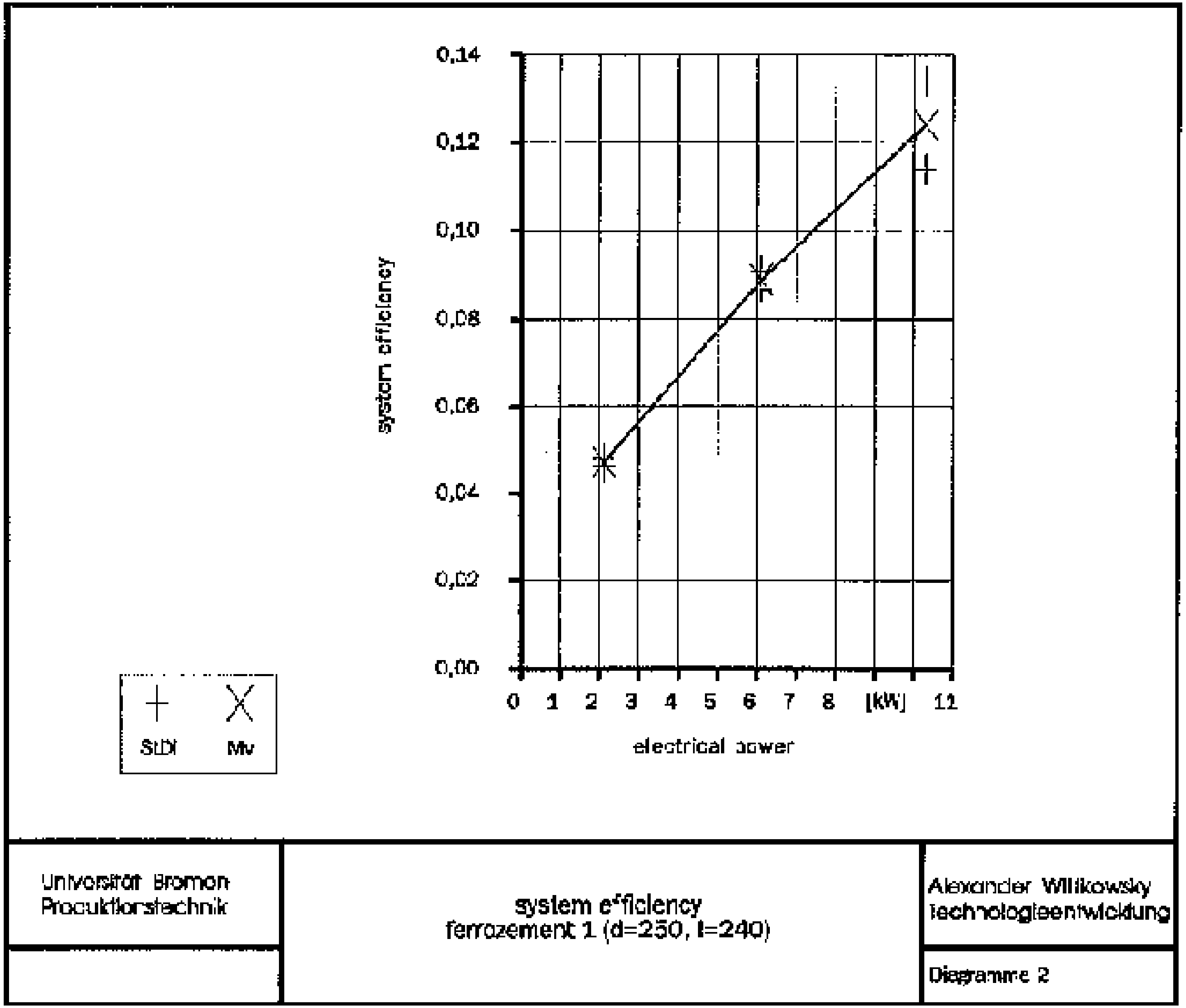


FIGURE

The performance data largely depend on the mechanical resp. electrical load, connected to the engine. The values in table I resulted when a 6-cylinder engine

with 2.0 cylinder volume and a speed of 2,500 rpm was connected, linked to a 3-phase alternator powering an electrical load (stove plates).

Diagr. 1 and 2 show very clear that the "nominal operation" of the gasifier has to be defined clearly. In diagr. 1 the specific fuel consumption of the ferrocement gasifier is plotted for three load situations (2, 6 and 10 kW). At 10 kW (which is a bit below the maximum power of 12 kW, which can be reached with he 2 liter engine) the fuel consumption per kWh is much less than at the load 2 kW. This is reflected as well in the overall efficiency of the system (the relation of usable electric energy to the energy content of the fuel): The efficiency is much better on 10 kW than on 2 kW.



FIGURE

This tendency is obviously common to all types of gasifiers and has to be recognized:

A gasifier has a narrow range of optimum performance. A deviation from the optimum working condition results in less efficient use of fuel, less operational stability, and less economic viability.

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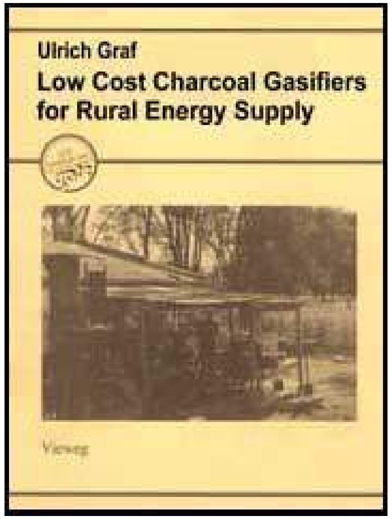


Low Cost Charcoal Gasifiers for Rural Energy Supply (GTZ, 1994, 49 p.)

7. Derived technical demands for field application of gasifier-engine systems

The following considerations are limited to stationary gas producer plants for mechanical and electrical energy supply. The use of process heat is a further important application, but is not treated here as not being within the terms of reference of the project.

7.1 Issues in engine operation

As soon as a hot charcoal bed is established in the gasifier and the hot combustion gases are driven by suction or pressure through the charcoal layer next to the combustion zone, gas production begins. As soon as the pipes and vessels between gas producer tank and engine inlet are filled with gas and the gas is mixed with the adequate amount of secondary air, the engine should start.

The performance of the gasifier depends first of all on the engine characteristics. The adaptation of the engine to the dimensions and performance of the gasifier (or vice versa) is essential to the performance of the complete system. The engine has the correct size, if its gas consumption (dependent on cylinder volume and revolutions per minute) in nominal operating conditions corresponds to the nominal gas production of the gasifier. Details of this correlation are often not sufficiently understood by operating personnel and even involved technicians. It is well known that gas production can vary within a certain range, depending on the suction of the engine. The relation between maximum and minimum gas production is often called "turn down ratio". But it is not clearly defined which numeric values of gas flow are to be expected at a given gasifier and a given engine.

It is obvious that the lower and upper limit of gas production is defined by the involved amount of charcoal. Less obvious is the dependence on the geometry of the reaction chamber (diameter and height). This paper is not the adequate place to go into too many scientific details, let us take it as an empiric result that a height of the reaction cylinder of 20 cm and a diameter between 25 and 30 cm is most suitable for an engine shaft power of 10 kW.

If an engine of 2 litres cylinder volume is used, the minimum number of revolutions is approximately 1400 rpm, which corresponds to a gas-air-mixture of 60.42 Nm^3/h entering into the engine and a gas production of 28.7 Nm^3/h in the gasifier. It was found empirically that less gas production than the above given value result in too low temperatures in the reaction zones. This freezes the kinetic reaction and results in very poor gas quality. The upper limit of gas production of the 25- 30 cm diameter hearth should theoretically be indicated by a decrease of the gas heating value, when the involved charcoal is just burnt by an excessive oxygen supply, leaving no charcoal bed for reduction of the combustion gases. In practice, this could not be observed in test runs of the FLEUS group, as gradual overheating of the materials (refractory, cement walls, cooling water) began when 12 kW shaft power were exceeded.

The practical consequence of these considerations is:

(1) A reasonable engine speed is 2500 rpm. This is a good working point for the combustion engines, where good torque can be expected. Too high speed can be critical in terms of insufficient lubrication and cooling.

(2) A cylinder volume between 1.8 and 3 liter is adequate for the standard open core gasifier. This will render between 8 and 15 kW at 2500 rpm at full load operation. For loads higher than approximately 6 kW, good cooling by a continuous water flow through the system is necessary (depending on ambient temperatures). For a 3 liter engine, a reactor diameter of 300 mm is adequate.

7.2 Typical applications

At stationary engines, a mechanical or electro-mechanical speed control device (governor) has to adjust the gas valve in order to maintain the nominal engine speed under the varying load situation (whereas in vehicle driving the engine revolutions are controlled by the driver with the accelerator pedal). Stationary diesel engines are always equipped with such a governor. In practical application of gasifiers however, very often a car engine for gasoline operation is used. These engines can run completely on gas (whereas a diesel engine requires dual fuel operation) and are much cheaper than a diesel engine, but the absence of a governor for speed control may present a problem. This is especially true in applications where the plant is running at constant load and the presence of the operator is only needed for refilling the fuel bunker. In the following it will be discussed in which cases a governor is absolutely necessary and in which cases it is not. There is a wide range of possible applications of gasifier-engine-systems, but it is possible to define a few typical situations. They are typical with respect to the capability of the engine to follow the load and retain a constant speed.

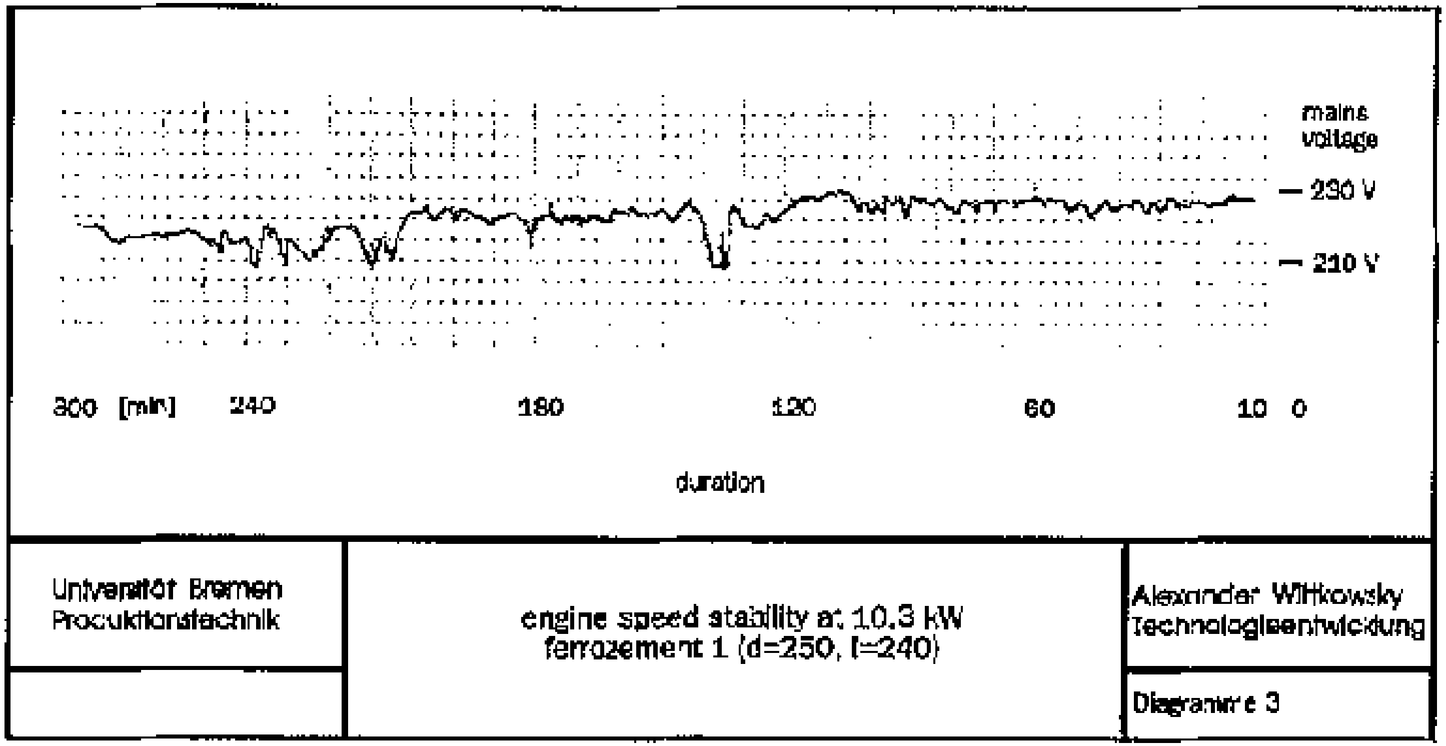
Case 1: Constant mechanical load, no need for stable engine speed.

A typical example is the water pump. A pump, working on nominal revolutions, delivers a certain quantity of water over a certain height within a certain time. If the revolutions of the pump are fluctuating, the quantity of delivered water will fluctuate accordingly, but the pump will still work. The acceptable range of fluctuation will be approximately + / - 20 % of nominal rpm. If the gas production and the gas quality of the gasifier is constant enough to meet the energy demand of the engine-pump-set within these limits, a governor is not necessary.

The derived technical demand for water pumping application is:

Even without a governor, the gas production by the gasifier has to be sufficiently constant to maintain nominal engine speed +/- 20 % over the time interval between two refuellings (4 hours).

Diagramme 3 shows the variation of engine speed of the 2 liter Ford engine of CHAR, connected with the standard ferrocement gasifier. The constant load is here simulated by electric heaters, the engine revolutions are directly proportional to the indicated electric voltage. It can be seen that the demand for constant rpm + / - 20 % is met without problems.



FIGURE

Case 2: Variable load, no need for stable engine speed

The power demand of working machines is in most cases characterized by a steep increase from no-load to full load. Neither the no-load situation nor the full load situation is bound to an exactly defined engine speed: No-load condition can be maintained by idling of the engine, but as well by rather high revolutions. For example, a circular saw is running at high rpm without load and is decreasing the speed when the load is put on. The engine speed under load should be sufficiently high to get the necessary power output, but it is not necessary to keep the number of revolutions stable. The situation gets additionally complicated when electric motors are switched on under load (e.g.: Compressors in refrigeration units), as in these cases the initial electric current through the electric coils is very high, resulting in a power drop in the electric line and reduced starting torque.

The wide range of necessary adjustment of the gas valve can normally not be covered by a governor, it requires manual adjustments. But, as these applications require personnel for the working process anyway, it should not be a problem to have a hand on the adjustment valve at the moment when the load is added.

The derived technical demand for working machinery application is:

The load following capacity of the gasifier must be sufficient to react on load changes between 20 % and 70 % of maximum load. Manual adjustment of the gas-air-mixture supply' valve is acceptable.

Applications of that kind, tested successfully with the standard ferrocement gasifier and a 2 liter engine, were:

- **circular saw, 40 cm diameter, cutting of hardwood 10 cm thickness**

(power demand approx. 4 kW)

- a small mulcher for straw and branches (simultaneously to the circular saw, two engines running on one gasifier)

- electric welding (power demand 7 kW on 125 Amperes welding current)

- electric load (stoves and heaters) varying in steps between 2 and 10 kW.

In all these cases, very short load following frequencies were possible, as long as the load did not exceed approximately 70% of the maximum power.

Case 3: Low fluctuations in electrical load, but need for constant engine speed.

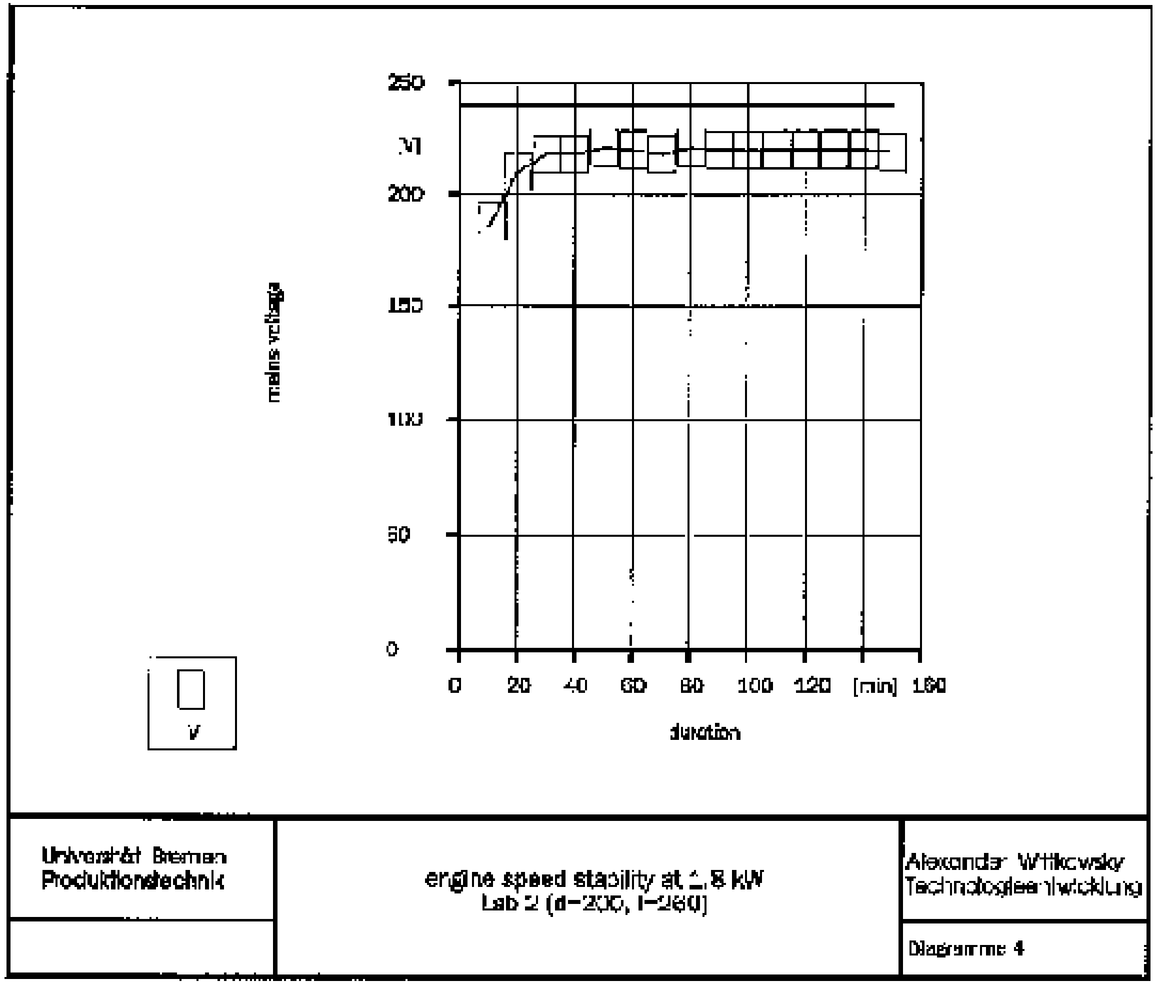
This is the case of electricity supply for small local grids (village electrification). Electronic instruments like radio, television, light bulbs etc. require constant voltage and frequency, and this means constant rpm of the engine within + / - 5 % of the nominal rpm.

A gasifier engine system will normally not provide a constancy of gas quality, sufficient for this demand. Furthermore, minor fluctuations of the load cannot be avoided. Therefore, a governor is essential. Even then, good performance of the gasifier is required to guarantee trouble-free operation over a period of a few hours.

The derived technical demand for application of a gasifier for small scale electrification is:

Constant voltage + / - 5 % deviation must be provided by the gasifier-engine system over the time interval between two refuellings of the bunker (2-4 hours).

Diagramm 4 shows the performance of the small metal gasifier, operating an engine with electric generator. The engine speed is controlled by a mechanical governor. The electric voltage is constant over the measuring period (2.5 hours) within + / - 5 % of 220 Volts. The electric load consists of a heater, different bulbs (incandescent and fluorescent), a radio and a television set.



FIGURE

No corresponding diagramm is available for the ferrocement gasifier, as a governor for the applied engine was not yet installed. The good constancy even without governor, shown in diagr. 3, assures the satisfying performance with governor for electricity application.

The conclusion of the results of a large number of test runs is:

(1) The standard ferrocement gasifier, coupled to a 2 liter engine, can be used for mechanical or electrical power applications between 2 and l2 kW. l0 kW is the recommended nominal power, which guarantees the best ratio between costs and output as well as the best overall efficiency.

(2) In water pumping applications, a governor for engine speed control is not necessary. The gas production is stable enough to maintain constant engine speed within two filling periods of the fuel bunker (2 - 4 hours).

(3) In applications for working machinery (grain mills, saw mills, grinder, cutter; electric welding, compressors the load can be varied between 20 and 70% of nominal power without relevant delay, if the gas demand is adjusted manually. A governor may, make the adjustment easier, but will not be sufficient for complete automatic control in many cases.

(4) For electricity supply for household applications, a governor is recommendable to guarantee stable voltage within two filling periods of the bunker.

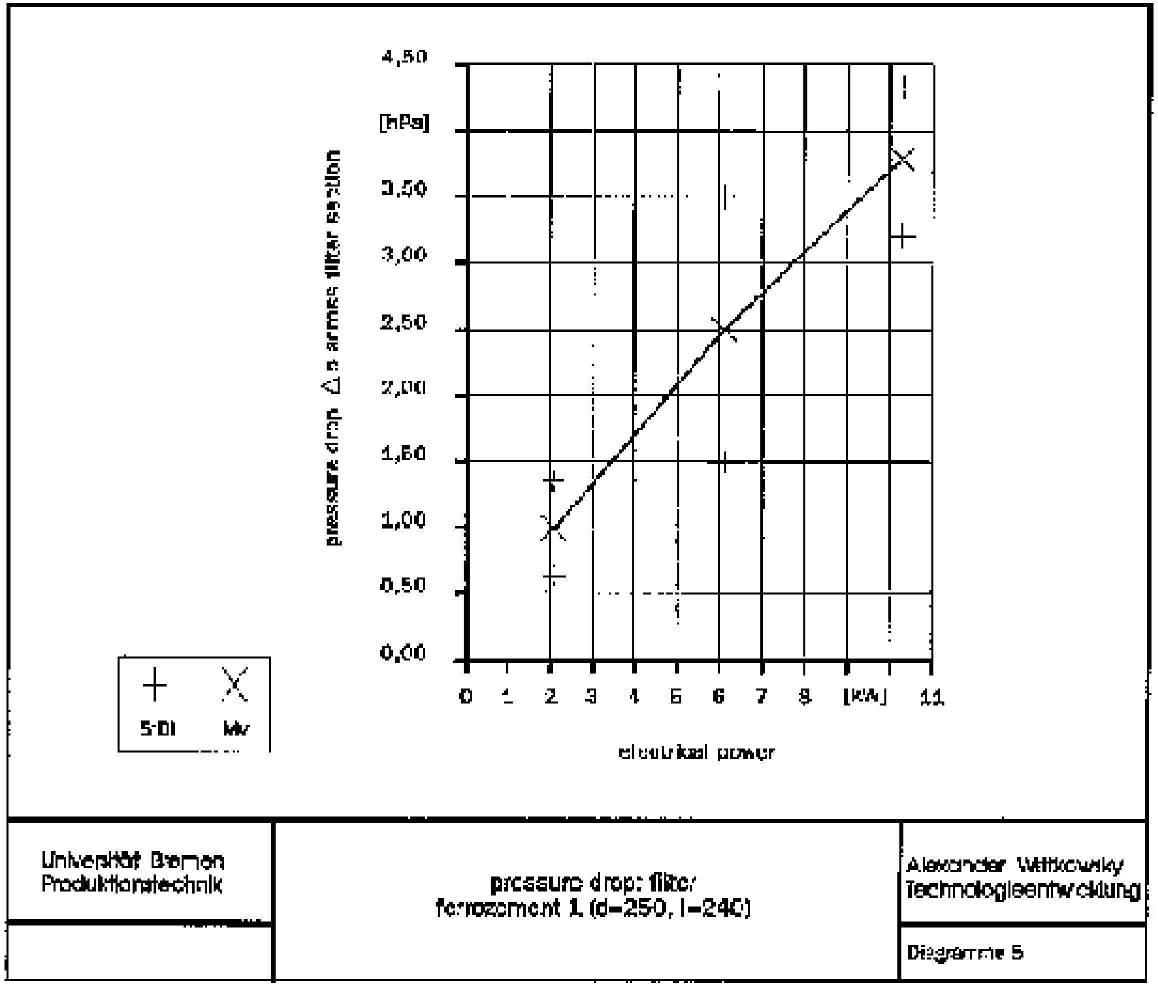
It must be emphasized that the laboratory results in Bremen were obtained with charcoal of constant quality (carbon content 87.7 %, heating value 31 380 kJ/kg, moisture content d.b. 5 %, ash content d.b. 1.2 %). The behaviour of the large variety of charcoal species from tropical wood is still subject of investigation. Generally, it can be concluded that the charcoal has to be reasonably dry and selected to sizes of 1-6 cm length.

7.3 Repair and maintenance of the ferrocement gasifier

It is a decisive advantage of the ferrocement gasifier that no corrosion of materials is to be expected. Whereas all metal plants-if not made of expensive stainless steel-corrode rapidly and have to be repaired by welding or replacement of components after one or two years, the ferrocement vessels and tubes are basically maintenance-free. This is especially important when the gasifier is not used all year round. A metal gasifier will just corrode away if it is left for some month without having been carefully cleaned and painted. A ferrocement gasifier is not affected at all by moisture and climate.

If there appears any rupture during operation, this may be the result of overheating when not enough cooling water was used. In that case, however, the repair is very easy by just chiselling up the rupture and adding new mortar to it.

A repair which is frequently necessary at classical metal gasifiers is the replacement of sealing ropes, nozzles, threaded tubes, hinges and so on - all these parts are affected by heat or corrosion. These sensitive parts are virtually non-existent at the ferrocement gasifier. The simplicity of the design avoids nearly all of the traditional repair problems.



FIGURE

The only necessary maintenance work is the replacement of the filter bags, when they are too contaminated. It is recommendable to have a second set at hand. The replacement is then done in 10 minutes. The replacement intervalls depend on the average load of the system; as a rule of thumb, every 100 hours (or once a month) is a typical interval. Diagr. 5 shows the average pressure drop across the filter section at various loads.

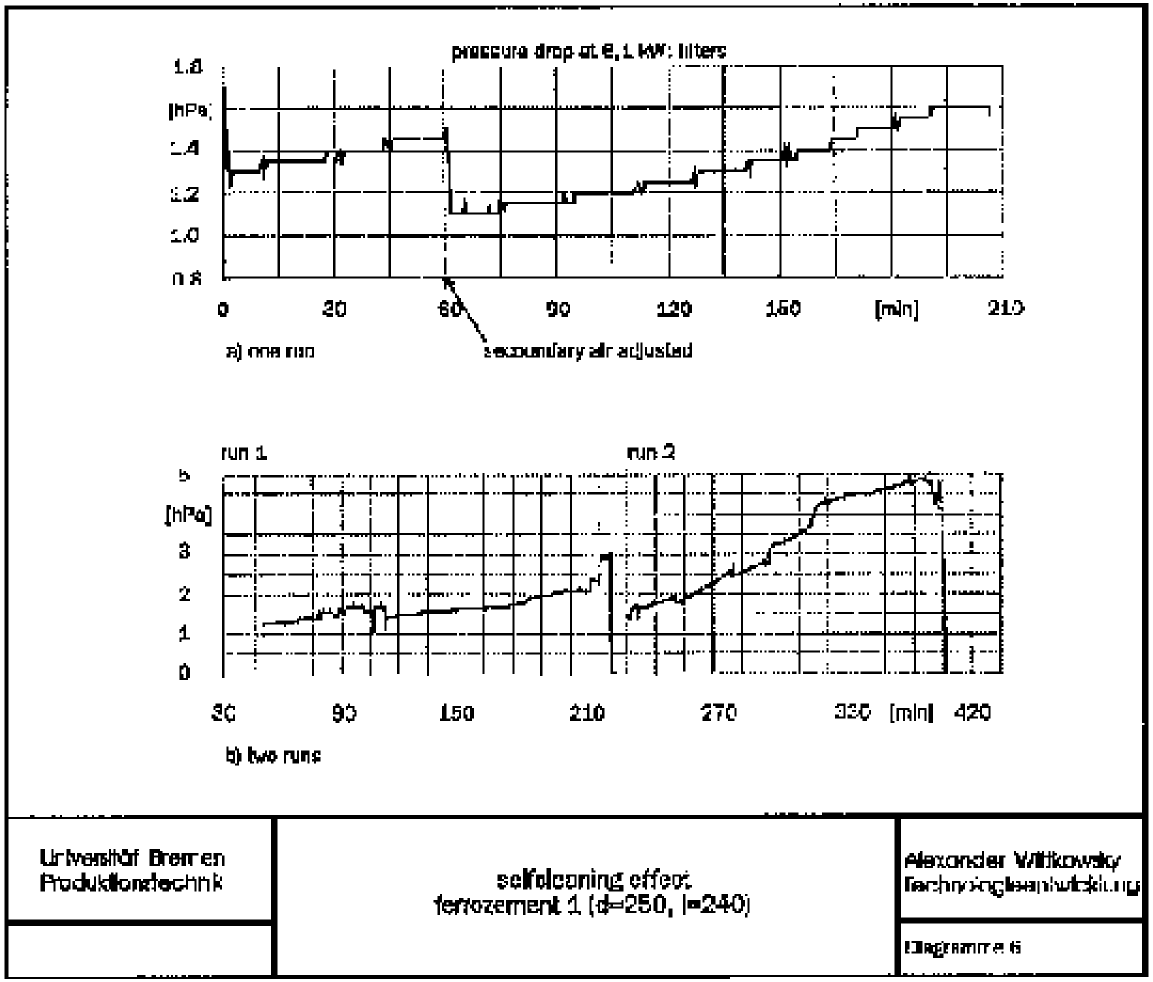
Diagramm 6 shows the pressure drop across the filter system over a period of 3.5 hours and over two subsequent test runs. It can be seen that a self-cleaning effect takes place: By the sudden collaps of the filter bags, when the suction of the engine stops at the end of a run, the dust layer on the filter clothes is partly removed.

A pressure gauge at the gas outlet is a very recommendable device for control of the filter performance. Even if the operator is experienced enough to know when the filter has to be changed normally, a defect in a filter bag can result in a clogging of the safety filter and a decrease of engine power.

Events of that kind are indicated by a sudden increase of the pressure drop across the filter units.

The ash removal from the ash container (under the reaction cylinder) should be done daily, together with the cleaning of the grate, before the new start. It is recommendable to let a layer of ash or sand continuously at the bottom of the ash box as a thermal protection of the cement.

The removal of deposits in the two settling chambers should be done once a month (together with the servicing of the filter bags).


pressure drop at 6,1 kW; filters
[hPa]
[min]
a) one run
secondary air adjusted
run 1
run 2
[hPa]
[min]
b) two runs
selfcleaning effect
ferrozement 1 (d=250, l=240)
Alexander Wittkowsky
Diagramme 6

FIGURE