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The Heat Generator

by Reinhold Metzler

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THE HEAT GENERATOR

A device to convert mechanical power directly into process heat

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SKAT

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A device to convert mechanical power directly into process heat

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Increasing production is very often the only way to achieve economic development. In rural societies, it is often small, agro-based industry which lends itself to this. However, the energy issue inevitably involved, has never before in history been as critical as today. Where the potential exists, small hydropower development offers a very effective escape from the energy-bottle-neck. Recent experience in Nepal proves this point. Small, turbine driven mills spring up at the rate of forty to fifty units a year, providing much needed processing facilities to the population at economical rates, and an attractive income to growing numbers of enterpreneurs.

The research project at Furtwangen, of which the heat generator is the result, very appropriately applied the principle of matching energy sources and harnessing devices to tasks or end uses. According to this principle, the aim is to avoid unnecessary conversions of energy to the largest possible extent, thereby achieving the highest possible ratio of energy efficiency versus investment cost. Specifically, the conversion of the kinetic energy of falling water into electricity - the highest grade of energy at present known - and thereafter reconversion into a lower grade of energy such as medium range process heat, is not according to the aforementioned principle. The heat generator on the other hand, strictly adhers to the principle outlined and is therefore - at least in the context discussed here - much

preferable. This is not a preference on merely philosophical grounds but rather for practical reasons. The heat generator introduced with this publication considerably widens the scope for small village industries. It is not only relatively simple to build and operate, but is also energy efficient, requires comparatively low capital investment and is very versatile in the end use of process heat. It is perhaps the most important factor that the technology involved does not require levels of skill which are higher than those already existing.

Efforts are under way to disseminate the technology developed in Nepal, where, in many cases, the heat generator can rather simply be added to existing turbine mills. There is evidence that the potential for small water turbine installations, combined with a heat generator, is large also in other countries. The SKAT publication series "Harnessing Water Power on a Small Scale" in general, and the manual on the heat generator presented here in particular, are aimed at creating interest in these development subjects. Likewise, it is the aim of SKAT and of the project at Fachhochschule Furtwangen, to provide technical assistance in the implementation of such projects.

St. Gall, Oktober 1983

ACKNOWLEDGEMENT

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1.0 INTRODUCTION

1.1 THE AIM OF THIS MANUAL

The application of waterpower on a small scale has become more and more attractive. The issues of developing sites for hydropower and appropriate turbines and generators is widely discussed [1, 14, 15]. Very little consideration, however, is given to the productive enduse of the power developed. The result of this is on one hand well built hydro plants with a very poor utilisation factor, which makes them often enough totally uneconomical and on the other hand plants producing electricity with a high standard where perhaps only mechanical power or heat is required.

There are a few projects which have recognized this problem, and are trying to develop hydropower from the user's point of view [14, 15, 16, 17]. Approaching the problem from the consumer side, leads to plants very different from commercialy available ones. A lot of work in this direction has been done over several years in Butwal,Nepal [17]. One result of these efforts is the development of the heat generator. This machine represents basically a fluid brake, converting mechanical energy of a turbine directly into heat. This heat can be used in processes where firewood is up to now the only possible heat source. In 1979, the first tests began and by 1981 two pilot plants where installed, one for drying ginger the other for drying fruits and vegetables. Both were merely used to dry foodstuff using air of less than 60 degr.C. In order to be able to apply the heat generator principle to processes which need higher temperatures, more development

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work needed to be done. With the infrastructure available in Nepal it was difficult to thoroughly test the heat generator and do the necessary research. In 1981, a research and development project was started at the Fachhochschule Furtwangen in West Germany with the following goals:

1. To develop a heat generator-kettle system which is able to develop high enough temperatures for boiling processes.

2. To optimise the design with respect to efficiency and cost.

3. To design the equipment in such a way that it can be manufactured in the small workshops existing in Nepal and elsewhere.

    After reaching this goal, two demonstration units, which included heat generator and kettle, were built in Nepal in 1983. Additionaly, two small workshops started immediately to build units which are now used in paper making and rice drying.

    Results of these efforts are recorded here with the aim of making the specific development experience available to others. It is important to realize, that the processes described and the design used here are related to the specific situation in Nepal. Generally speaking, this means: mountaineous areas with many small rain and spring fed rivers; no roads, all transport done on porter's back; the only available fuel is firewood and kerosene; the workshops for manufacturing the equipment have only basic machinery and

general workshop equipment. Therefore this manual cannot be a cook book for heat generators. If the approach, or the designs described in this manual should be applied in another country, they will certainly need changes to be appropriate to the different situation found there.

This manual attempts to give an idea of the Nepali context and of the approach taken within the project.

1.2 THE MAIN ENERGY SOURCE IN NEPAL: FIREWOOD

If the Nepalese proverb "The forest is the country's wealth" is correct, then the dramatic situation of Nepal is indicated by its depleted forests. A study by Tribhuvan University [1] has shown, that if there is no change in the present rate of consumption there will be no commercial forest left in the hills by 1985. Then the forests of the plains will have to supply the hills as well and they too will be exhausted by 1989. Keeping in mind that 96% of the population cooks its food with firewood, a disastrous energy future is predicted for the rural population.It will severely affect the two most vital necessities: food production and its preparation.

- The forests are the only natural way to control, by retention, the enormous water masses brought down by the monsoon. One of the reasons for the annual heavy floods in the Ganges plains is the extensive deforestation of the hills of Nepal.The resulting erosion means loss of urgently needed top soil for the production of food for

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Nepals growing population.

- Firewood, practically the only source of energy for the
  rural population (approx. 96% of the population),
  accounts for 87% of Nepal's total energy consumption [1].

"By all indications this supply is worsening rapidly.   It
is reported that fuelwood prices are up 80 to 100% over
those of five years ago.... The physical and temporal
costs of firewood collection by individual contractors are
reflected in the price charged for fuelwood.   The
significance of collection costs becomes readily apparent
during the monsoon season, when suppliers raise their
prices, sometimes as much as 100%" [18].

- "Much of the processing of agricultural products and
  small-scale manufacturing requiring process heat also
  depend, wholly or partially, on wood as a source of
  energy.   It is not only the traditional cottage and
  village industries that are dependent on wood fuel,
  however, but also the more modern establishments...
  Several aspects of industrial wood-fuel consumption render
  industrial demands particularly important from an
  environmental point of view. Industrial requirements tend
  to be significant not only in absolute quantity but also
  in concentration, both in terms of time and space.   The
  essentially seasonal nature of processing and
  manufacturing in Nepal often focuses the heavy fuel
  demands of industry during a few months of the year. The
  limited and rudimentary nature of the nation's road
  network, especially in the hill region, virtually
  guarantees that industrial wood fuel needs, particularly
  rural industrial needs, will be met by local forest
  resources. The concentration of manufacturing enterprises
  in response to the development of local markets, further
  compounds the impact of industrial wood fuel use." [18]

1.3 THE ROLE OF MICRO HYDROPOWER

Water power is the only form of energy, Nepal has indigenously and abundantly. The hydropower potential is estimated to be 83.000 MW, but only 0,07% of it is used to date. His Majesty's Government recognizes the keyrole microhydro (under 100 KW) could play in the decentralized development of the remote hill areas of Nepal. Power plants smaller than 100 KW would make it possible to rely on Nepals own resources and enable the production of the necessary equipment in indigenous workshops.[2]

Several workshops and institutions have been trying for a number of years to contribute their share to solve the energy crisis in Nepal. One of them is the United Mission to Nepal(UMN), an organisation of about 30 international mission societies. Part of UMN's Butwal Technical Institute, a training-cum-production unit, is the Butwal Engineering Works Pvt. Ltd. (BEW). This mechanical workshop has manufactured small water turbines for the past seven years. From the experience of other workshops it became apparent, that the surveying- and installation side is the bottleneck of developing small hydro and disseminate appropriate technologies. Experienced people are needed in the field and if they are taken off the production in the workshop, manufacturing is hampered badly. A separate "Small Turbine and Mill Project" was established, with the responsibility for surveys, installations and keeping in contact with customers. The project consists of four field teams of two men, a business chief and an accountant.

The project has installed 90 turbines by (1983), all in the remote hill areas. Most run village mills, which consist generally of three machines: rice huller, flour mill and oil press.

In these cases the turbine either substitutes for the expensive diesel engine or for the hard manual work needed for the traditional ways of crop processing. The advantage of a turbine driven mill over traditional methods is best shown in oilpressing. The "khol", a wooden oil press, takes about 25 times longer to process the same amount of mustard seed as the oil expeller in the mill. With maize and wheat the hand driven "janto" takes 9 times longer than the mill. Prior to the installation this hard work was done exclusively by women, who are responsible for food preparation. Manual labour is very short in the peak season and therefore the mill is appreciated for saving time and labour [3].

A second area in which micro hydro should play an important role, is to aid small industry in the hills by reducing dependency on wood as fuel and to encourage the establishement of new cottage industries by supplying its energy needs. Looking at some of these industries two points become evident:

- there exists an established small scale industry for the processing of agricultural products in the hills, which unfortunately uses only firewood as a heat source.(see chapter 2)

- newly introduced processes could strengthen the economy and could provide alternative employment. But they should not, as some examples show, use the already scarce firewood as energy source.

To be able to apply micro hydro for this field of small scale industry the heat generator was developed. The machine converts the mechanical power of the turbine directly into heat, which can be used for processes described in chapter 2. In principle the heat generator works very much like a fluid brake. In these brakes the rotor stirs a liquid, thereby creating eddies which heat up the liquid. The heat created is equivalent to the mechanical input at the shaft of the rotor (Joule's experiment). If heat is the energy form required, this principle is the simplest and cheapest method of converting mechanical energy. The heat generator described here uses air instead of a fluid for reasons described later. It produces temperatures up to 250 degrC, which make the generator applicable to processes using firewood up to now. The application covers especially drying, boiling, destilling and concentrating of agricultural products.

If used for drying, the heat generator forces hot air (<80 degr. C) over or through the products to be dryed. This gives, apart from the saving of firewood, a definite advantage over the traditional ways, which rely on natural convection.

At higher temperature levels, a kettle is added in which boiling, distilling and concentrating can be done. It is also possible to produce steam, needed for many processes in food technology.

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2.0 HEAT REQUIREMENTS IN RURAL NEPAL

In this chapter some processes shall be described which are already established in Nepal and have a high heat energy consumption. In each of these processes, the use of the turbine driven heat generator could substitute for firewood. The list of possible uses of the generator is by no means complete, but is only an attempt to give an idea how it could be applied.

2.1   DRYING OF AGRICULTURAL PRODUCTS

2.1.1 SPICES AND HERBS

Spices are a cash crop in Nepal and therefore any improvement in processing means a direct increase of the farmer's income. Ginger [4] may stand as an example: It is a rhizome with a moisture content of 80-85% which has to be reduced to 12% by drying for save storage. To achive this, 10 kg of firewood is needed to dry 1 kg of ginger. One panchayat (roughly 6oo inhabitants) in the midwest of Nepal grows 100 metric tons of ginger per year. This amounts to roughly 1000 tons of firewood per panchayat!

Another fuel consuming process is drying cardamom. Being a member of the ginger family, this perennial plant grows in shady, damp ravines in the eastern hill region of Nepal.   Its seed pods, which must be dried immediatelly after harvesting, provide the spice known as green cardamom. Because of the generally wet weather conditions prevailing during the harvest period, the cardamom must be dried in ovens heated by

firewood.   Popular as a cash crop with the farmers, cardamom
is being promoted by government officials. Commercially this
spice figures significantly in Nepal's export trade. However,
12 kg of firewood is consumed for every kilogram of cardamom
introduced into the oven.

Other spices like pepper and chilli are traditionally
dried in the sun. With larger quantities this is difficult
since a lot of space is required, which needs to be guarded
against animals.   Unexpected rain and unreliable sunshine
slows down the drying process, thereby endangering the crop by
mold and germination.

Herbs, containing essential oils, are found widely in the
hills and their oils are used for medicinal purposes and for
the perfume industry. A rather big project has been initiated
by the Government to use this resource. Prior to extraction
of the oils, the plants need to be dried.   A controlled
temperature is necessary, otherwise oil is lost by evaporation
or is destroyed by too high temperatures, which can occur when
drying in the sun.

2.1.2 RICE

Improper drying is one of the main reasons for postharvest losses in rice. Studies [5,6] have shown, that those losses, caused by insufficient drying, can be as high as 5% of the whole harvest. Sun drying is the most frequently used method. Since sun drying is difficult to control, cracks in the kernels may develop, causing a high percentage of broken grains in the hulling- and polishing process. This leads in the end to losses and lower market value.

Another point is that, the climatic conditions in Nepal would allow a second rice crop. The harvest however, would fall in the monsoon season, which makes sun drying too unreliable with mold and germination endangering the harvest. This is one reason why growing this early rice is not common. Those farmers who do, have to sell their crop right after the harvest for a low price to big rice mills, thus growing of early rice is discouraged.

Decentralized, village owned dryers, powered by water turbines, could efficiently decrease losses of valuable foodstuff and income, thus improving food availability and the economic situation of the farmers in the hills.
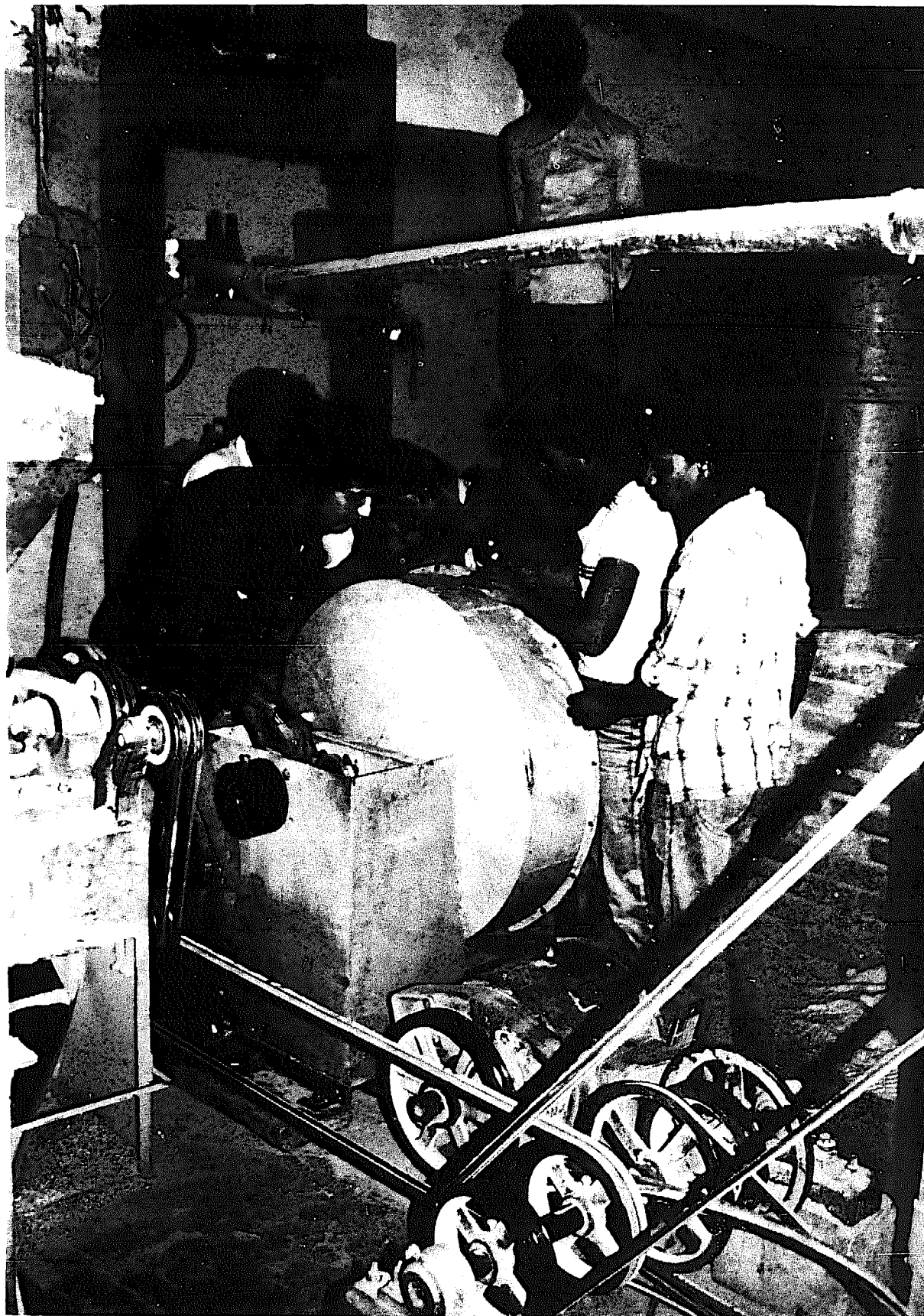
FIG.1: A HEAT GENERATOR, INSTALLED IN A MILL, DRYING RICE

2.1.3 VEGETABLE AND FRUITS

The Government of Nepal emphasises the value of vegetable and fruit growing. One of the biggest problems, however, is the difficulty of storage and transport. Fruits and vegetables can be stored and transported easier when dried because of reduced weight and volume [2].

There exists a significant market in dried fruits, especially for trekkers. Up to now this demand has been met by expensive imports. Vegetables, an important supply of minerals and vitamins are only seasonally available in most areas of Nepal. The profit margin is small, since, at the time of harvesting, the market is flooded with vegetables. As a result, growing vegetables is of little economic interest. Also, the erratic availability of vegetable is one of the reasons of malnutrition in Nepal.

Artificial drying could change the situation considerably by prolonging the possible storage period, and by opening new markets.

2.1.4 TEA AND TOBACCO

The East of Nepal is well known for its "Ilam Tea". This is one of the few exportable commodities of the country and therefore a source of urgently needed foreign currency. To dry the tea leaves, artificial heating is necessary. For 1 kg of dryed tea, 4.8 kg firewood is required![18]

Growing tobacco for the only cigarette factory in the country provides a good cash income for another group of farmers in the area. To cure the tobacco leaves, artificial drying is necessary. Huge amounts of firewood are used to achieve this: 7.5 kg wood, for every kg of tobacco ![18]

Some figures, given by the Tobacco Development Corporation in Janakpur, may give an idea of the absolute quantities used in tobacco drying:
The corporation has 800 curing barns to cure the tobacco grown in the Janakpur area. Each curing barn uses approximately 28,000 kg of firewood per year. This makes a total consumption of 22,400 metric tons per year in this area! The demand exceeds the regenerative ability of the forests and it gets more and more difficult each year to find this enormous quantity of wood. The national newspaper "Rising Nepal" reported on 2.Nov 1980, that the situation is so serious, that even fruit trees are felled to heat the curing barns.

2.2 BUTTER FAT

In order to prevent butter from turning rancid, the water is driven out by heating it up to the boiling point. Thereby the butter turns into butter fat, the "ghee". This process is done in the farmhouse over the open fire. Apart from the low efficiency of an open fire, firewood consumption for this process is relativly high: 4 kg of wood for every kg of ghee [18]. Butter fat can function as cash in the village economy and can be saved or sold according to the financial situation. Although the bulk of the product is consumed locally, a

considerable amount is exported to India, thus it has become an important source of cash income for the hill farmer.

For processing the relativly small amounts , village scale cooking kettles could be installed. Again, a turbine driven mill, complemented with a heat generator, would readily lend itself to this purpose.

2.3 PAPER

Paper making has a very old tradition in Nepal, the craft having been handed down from generation to generation. Since ancient times, hand made paper has been used extensively for such diverse purposes as manuscripts, horoscopes, incense making, kites, curtains for windows, tanka printing, stamps, wrapings etc. Nepali hand-made paper also finds a special use in legal and other special documents in the country. Today it is also used for making files, albums and invitation and visiting cards. Due to its unique nature, its high tensile strength and folding capacity, the product is now gaining popularity on the international market. [7]

To produce it, the bark of the Daphne plant is soaked in water, cleaned and then cooked in ash lye or caustic soda for 5-6 hours. The pulp is then poured on moulding frames. Water is drained off, leaving a thin film of pulp on the screen of the moulding frame - the paper. The frame is then put out in the sun for drying.
The consumption of firewood during the boiling process is quite high, and amounts to 21 kg per kg of paper. It is

expected that lack of firewood rather than pulping material will be a constraint to further hand made paper production in the central hills [18].

Another problem is the sun drying of the sheets:

- if the weather changes after the sheet has been put out into the sun, and drying takes too long, mold is likely to destroy the sheet.

- due to the slow sun drying, only thin paper can be produced, since thicker sheets would take too long to dry. This puts an economic limit to production, since it increases the required number of frames. Additionaly, mold becomes a problem again.
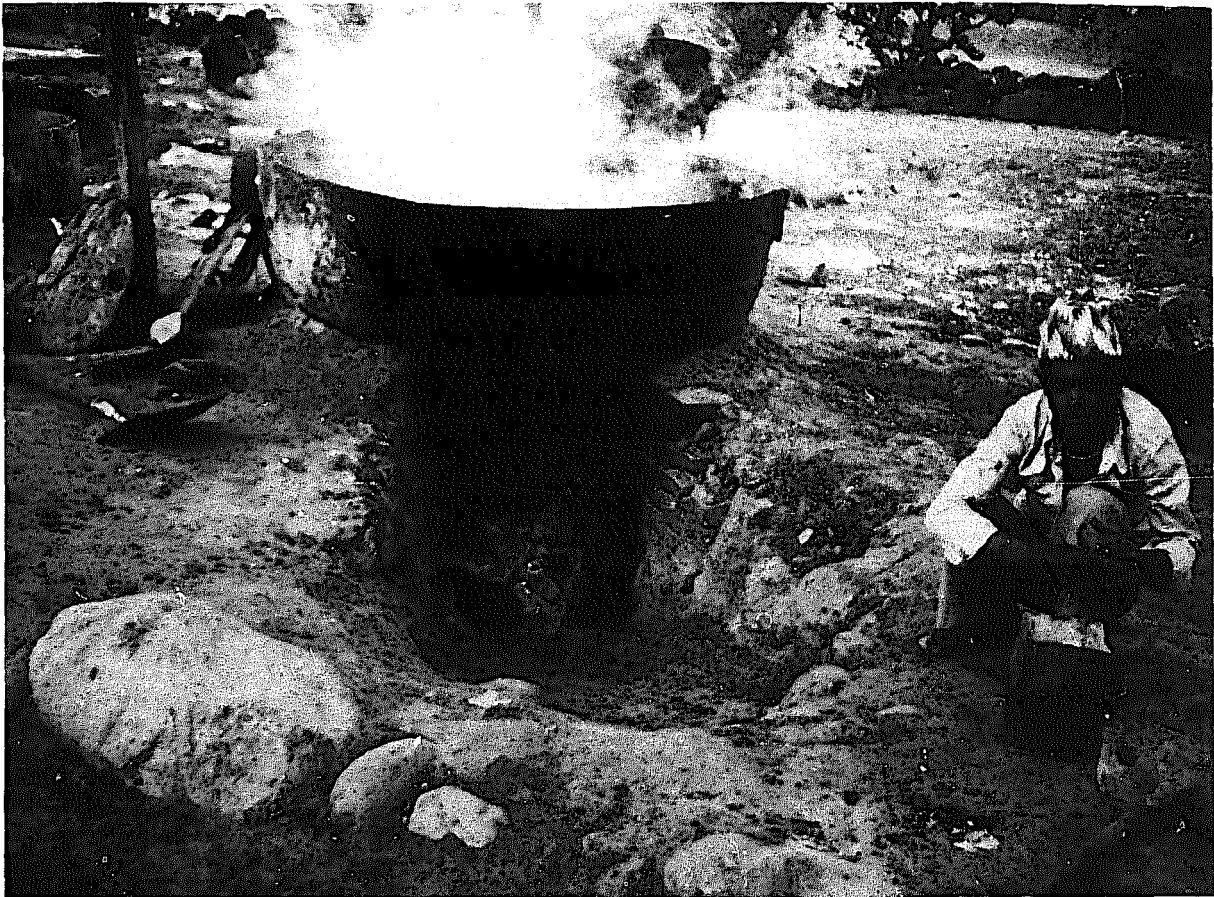

FIG.2: TRADITIONAL PAPER MAKING
(Photo by HELVETAS)

A turbine powered heat source would have a twofold advantage:

- The enormous firewood consumption would be eliminated and with it the significant work input necessary to collect it.

- Mechanical drying would eliminate sun drying as a major bottleneck in paper making. It would also enable the paper makers to produce a larger range of paper qualities, especially thicker paper.

First trial runs have been undertaken in Butwal using the heat generator to boil the pulp and dry the paper.

2.4 SOAP

To produce soap on a village scale, oil from seeds, for instance of "Chiuri" trees (Bassia Butyracea) is pressed out and carried to the closest commercial centre, which is often 2 days walk away. There, the oil is boiled together with caustic soda for 10 to 12 hours in a small factory, poured into moulds and after setting, cut and packed.

FIG.3: TRADITIONAL SOAP BOILING

A small, turbine powered soap factory in the hills would have several advantages:

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- In place of the very inefficient hand press, used to date, the already available oil-expellor of a mill could be used. A higher yield of oil, and at the same time less labour input, would make collecting and processing "chiuri" fruit economically more interesting.

- A hydro-powered heat generator would substitute for firewood. A small soap factory, producing 400 kg of soap per day, burns 200 kg firewood a day. Together with the processing problems of the seed, this is one of the major reasons, why soap factories on a small scale are only found in the plains, where transportation is not too big a problem. There they import their oilstock from India and are able to get firewood by truck from the few forests left over in the plains. The soap is then sold back into the hills. In this way the already disadvantaged hill areas loose important income and employment. Hydropower, the wealth of the hills, could bring soap factories into the hill villages. Hydropower has the advantage of a cheap energy source, an indigenous oil supply, and shorter transportation of both raw material and end product. The soap could be produced where the raw material and the market for the end product is located, instead of attracting the people of the hills to the plains.

- The growing of Chiuri trees would be encouraged. This tree, already indigenous to the country, grows relativly quickly. Bees make good honey from its flower nectar, the fruit pulp yields alcohol (and can therefore be used instead of grain) and the leaves can be used for cattle fodder, and the wood for cooking food.

In this way a soap factory could contribute to afforestation instead of adding to the depletion of the forest as in the present situation and give employment and income to the rural population.

2.5 PARBOILING OF RICE

Hulling of rice is heavy work, and is part of daily food preparation. Since ancient times man tried to make this process both easier and faster. Only the quite recently introduced rice mills have brought a significant improvement [8]. But, as is often the case with new technologies, the introduction of rice hullers resulted in severe drawbacks:

- Vitamines, especially thiamin, are found in the outer layer of the rice kernel. Due to the polishing effect of the huller, this outer layer is removed, together with the protein rich germ. This results in vitamin deficiencies. Nevertheless this machine has become quite popular. This shows how important it is to ease the hard work of manual rice hulling.

- In addition to the decrease in nutritional value there is a significant loss in rice through breakage and grinding dust. In India the loss to human consumption is estimated to be on the order of 9,6 to 11,6% of the country's harvest! [9]

These disadvantages can be prevented by parboiling which is one of the oldest processes in food technology [10]. Approximately a fifth of the world's rice production is parboiled. The process consists of basically 5 steps [12]:

1) cleaning

2) soaking (3-4 hours in water of 65 deg.C)

3) steaming (steam of a pressure of 1-3 bar)

4) drying (air of 45 deg.C)

5) hulling

The advantages of the process are considered to be:

- During treatment, the kernel hardens and the husk splits half open, which makes hulling much easier and at the same reduces breakage.

- The processed rice contains more protein, vitamines and minerals, since they diffuse into the kernel and are then not removed by the polishing process.

- Since the hardness of the kernel is higher, it is more resistant against insect infestation during storage.

- By parboiling, less nutrients are lost in the cooking water, which is usually discarded, thus increasing the nutritional value of rice produced by this process.

- Parboiling is approximately 6% cheaper than other common methods.[12]

Again, a problem is the heat source for water, steam and drying. A heat generator could produce the heat for soaking and drying, as well as the necessary steam. For the latter, further development work is to be done on the heat generator. With the implementation of this new heat source, parboiling on a village scale becomes feasible, especially if an already existing mill can be utilized.

2.6 CONCENTRATION

2.6.1 LEMON- AND LIME CONCENTRATE

Generaly speaking, growing of citrus fruits could be a good source of income. However, since they do not store well, the crop has to be sold when the market supply exceeds demand, and consequently, prices are low. It is very common to concentrate the juice in an attempt to avoid this loss of income. This is done by pressing out the juice of lemon or limes. The juice is then poured into thick walled pans, where it is heated by a wood fire, reducing the water content by evaporation. The concentrate plays an important role in the Nepali kitchen and is used as a flavouring. However, people complain about the expense in its preparation, firewood playing the biggest part in it.

2.6.2 BROWN SUGAR

In many areas of Nepal, sugar cane is grown on small plots. The cane is not processed in sugar factories as is done in the plains, because of prohibitive high transport costs. It is rather pressed in a simple crusher powered by an animal, then cooked in pans with a volume of about 100 ltr. The concentrated juice is then poured out into small moulds and sold as "gur", a substitute for the expensive, refined sugar. Firewood consumption amounts to 1 kg for every kg of gur [18].

These concentration processes are examples, where heat input helps to decrease weight and thereby the cost of transportation, to increase storage shelf life of foodstuffs, and most important, to increase the profit margin. In these and similar processes a turbine driven heat generator could substitude for firewood. There would be a definite advantage over the traditional method, as long as the installation is close enough to the village and processing costs are not excessive. The necessary investment would be quite low, as long as the concentrating equipment could be added to an existing turbine mill.

2.7   DISTILLATION PROCESSES

2.7.1   VOLATILE OILS

The Government of Nepal has clearly realised, that herbs growing in the hills represent a valuable source of exportable goods such as volatile oils for medicinal applications and as raw material for the cosmetic industry. To be able to start using this resource, the Herbs Production and Processing Company had been formed by the government. Since its beginning this company has quite actively pressed the case for small, decentralised processing centers, the only economic way to process herbs in the mountainous areas of Nepal. The idea is to gather herbs in a region, to dry them artificially and to extract the volatile oils by distillation.

Unfortunately, for drying and distilling, a lot of firewood is necessary. Therefore the company has approached BEW to supply a suitable heat generator driven by a 20 kw turbine, to produce hot air for the drying cabinet, and steam for the distillation plant.

It was found that a dryer installation together with a distilling plant for ginger oil would be a feasible village industry. One product of processed ginger is Ginger oil. It is obtained by distilling dried ginger slices. Fresh ginger contains 2% of oil, so that transporting ginger means actually transporting water and fibre. By this fact alone, it makes sense to process ginger on the spot where it is grown. Since ginger plays an important role in the village economy, every addition to on-the-spot processing, would improve the situation of a disadvantaged part of Nepali society - the

farmer in the hills.

Other sources of volatile oils are eucalyptus- and citrus plants.

2.7.2 ALCOHOL

FIG.4: ALCOHOL DISTILLERY

It seems to be important to every culture to produce alcohol. Fermenting and distilling, both at home and in small factories, can be found all over Nepal. The energy source is inevitably firewood and astonishing amounts are needed by any village distillery: 2.8 kg of wood for every kg of

distillate! [18]

The process is quite crude. The control of critical
temperatures is difficult to achieve and is one of the reasons
why the end product is often of poor quality and can even be
lethal.   If alcohol production cannot be avoided, it could at
least be improved by using an easily controlled heat generator
and thereby saving scarce firewood in the process.

2.8 DYING OF YARN

During the early sixties, Nepal was confronted with many
immigrants from Tibet entering the country.   Camps were
established in the hills, where today Tibetan carpets are
produced.   These carpets are number two on Nepal's export
list, only exceeded by jute, thus earning urgently needed hard
currency.

However, these small industries need enormous quantities
of firewood to heat the dying vats for yarn dying. 2 kg of
wood are needed to dye one kg of yarn.   [18] One of these
camps, Chialsa in Solukhumbu, uses 500 kg of firewood per day!
This amount is increasing every day, since high grade wood is
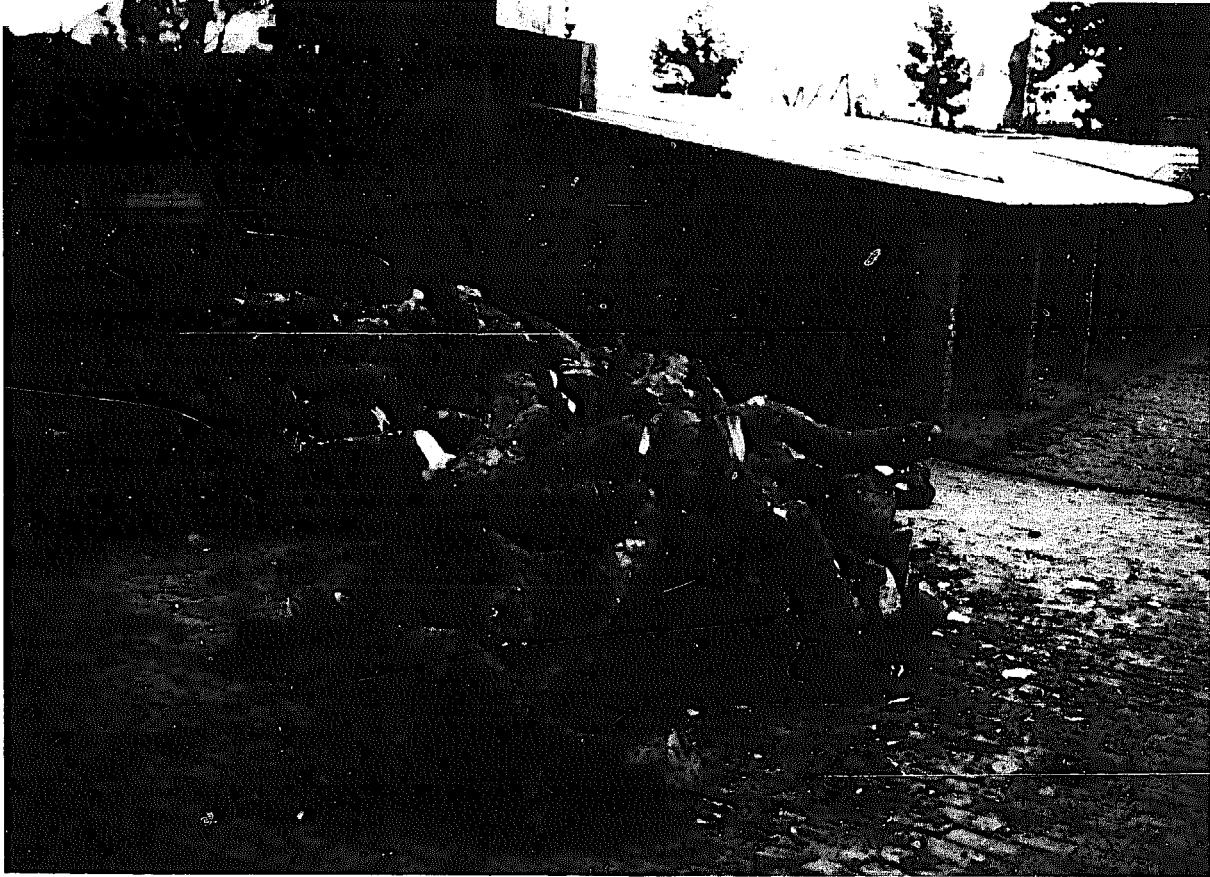no longer available in the area.

FIG.5:   WET FIREWOOD IN FRONT OF A TIBETIAN HANDICRAFT CENTRE

Dying of yarn is important not only in the carpet-, but also in the growing textile industry of Nepal and firewood, the only heat source in the village, is increasingly difficult to obtain.

2.9   CHEESE MAKING

Approximately 20 years ago, the Swiss Assosiation for Technical Assistance (SATA) introduced cheese processing in the hill areas. This was aimed at increasing the productivity of remote areas by improving the economics of dairy farming

through processing of milk. This programm is one of the few, which has proved to work without any foreign assistance after it had been handed over. It is one of the models which shows how important it is to introduce small scale plants for the processing of agricultural products and how this could be done.

Unfortunately, despite its obvious advantages, the project developed severe drawbacks. The energy requirement, which is not small, is met by firewood. The Pauwa cheese factory processes 1000 ltr of milk daily to make cheese and butter. The energy requirement for it, is given in table 1:

Table 1: Energy requirement for processing
1000 ltr. milk

PROCESS	QUANTITY	t2-t1	dT	Q [kcal]
PASTEURISING				
milk:	900 ltr	70-15	55	47.000
cream:	92 ltr	70-15	55	5.000
CHEESE MAKING				
heating:	828 ltr	45-30	15	12.000
culture preparation:	10 ltr	95-15	80	1.000
warm water for cleaning:	300 ltr	60-15	45	13.500
total energy requirement for processing of 1000 ltr milk				78.500 kcal

t1...starting temperature
t2...end temperature
dT...temperature difference
Q....required heat quantity to achieve dT

Using an efficiency of open fires, which can be taken as 12%, and a heat value of 3.000 kcal/kg for air-dried firewood, this is equal to a daily fuel requirement of 220 kg of wood. In the cases where hydropower is available, this requirement can be met by turbine driven heat generators instead of the less reliable and more expensive power sources of solar heaters and biogas plants.

2.10 SQUASH

Several years ago the Government began to encourage the growing of fruit trees in the hills, to create alternative income. However, profit on fruit growing is low since high transport costs is a major constraint.

Apples and citrus fruits have a high water content. It would be a great advantage to be able to process the fruits right on the spot to make squash, marmelade or jam, thereby increasing the market value of the end product leaving the hills. As an example, the energy requirement to produce 30 ltr squash is given in table 2:

Table 2: Energy requirement to produce 30 ltr. squash

P R O C E S S	deg C	kcal
-pasteurisation of 100ltr juice	15-100	8000
-boiling of sugarsyrup 270 kg	15-100	17000
-bottle cleaning water 6 ltr	15-80	40000
100 ltr	15-35	20000
-water for cleaning 500 ltr	15-60	22500
Total energy requirement approx.	100.000.	kcal

One turbine driven heat generator of only 5 kW output could provide this energy, saving approximately 280 kg of firewood for each 30 ltr. batch of product.

2.11 BAKING OF BREAD

Baking of bread on a village scale is also a process worth looking at. The enormous number of tourists trekking in the hills, and their different food requirements, resulted in the opening of many small scale bakeries along the main trails. Unfortunately, they produce exclusively white bread with low nutritional value. It has become a status symbol for Nepalis to buy this expensive low quality bread for their children.

A turbine mill in connection with a heat generator could supply the flour and the necessary heat for baking. Waterpower would take the place of the considerable amount of firewood needed by a bakery: 1,2 kg wood per kg bread! [18] Additionally, the bread would be more nutritious, since the

flour mills installed in these units can only produce brown flour. All those factors should contribute to a decrease in price and to an increase in nutritional value of the bread.

3.0 ALTERNATIVES TO FIREWOOD AS HEAT SOURCE FOR COTTAGE INDUSTRY

3.1 ELECTRICITY

At first glance, it seems obvious to convert waterpower into electricity for heating. A closer look, however, reveals that electricity is in many instances not appropriate at all.

In most places in the hills of Nepal, electricity is not known at all. Therefore, skilled manpower for repairs and maintainance of electrical gadgets is not available. Maintaining a power plant becomes very difficult, especially if it involves electronics, as it is the case with e.g. the voltage control of most commercialy available generators. The main advantage of electricity is to be able to conduct it to wherever it is needed. Of course, it is handy to have a mill or village processing center in the middle of the village, but it is expensive. The most decisive factor in this connection is capital investment. The following two examples give an idea of the price difference between direct heat generation and heating with electricity:

a) the energy from an existing turbine (25 kw output) is converted first into electricity, then into heat through heating elements and into kinetic energy through a fan, to be able to use it for a dryer.

b) the energy is converted directly into hot air by a heat generator and blown into a dryer close to the turbine.

This involves the following costs:

a) Electrical generator   US$ 4,200

   Control panel   US$ 1,500

   Heating and blower   US$ 300
   _____

                    total   US$ 6,000
                    ═══════════════════════

If the electricity is used for lighting as well, which would be the case in most villages, the additional cost would be US$ 7,600 (transformers US$ 1,300; transmission line 4km long US$ 6,300)

b) If the energy is converted to heat directly and the dryer is placed close to the turbine it would involve only:

   one heat generator with drive   US$ 800.-
                                     ═══════════

The advantage of a) over b) is to be independent with the location of the dryer and to power lights. The investment for this is 7.5 times higher than the installation with heatgenerator. If a transmission line with transformers is needed it is even 17 times higher. In very few cases this high investment can be justified. In most instances the convenience of location plays a small role, since the crop does usually not grow close to the village, and has to be carried anyway. The high price of electric light has been one of the main reasons why rural electrification projects have had a hard time to succeed.

Another aspect is efficiency: Supposing efficiencies of: Generator 80%, transformer 95%, transmission line 90% and fan and heater 95%, we get an overall efficiency of 60%, against 75%-80% in direct conversion with a heat generator.

3.2 SOLAR ENERGY

For many processes in cottage industry, solar power is the appropriate heat source. Up to now it has been successfully applied in drying and low temperature heating.

Main drawbacks, however, have been the relatively high investment costs and the unreliability of sunshine. Up to now, it can not be used economically for applications where higher temperatures are necessary, such as boiling and distilling, or where forced air is needed as is the case in larger grain dryers. Therefore, the strength of solar power seems to be in smaller scale- and low temperature applications, and where hydropower is not available.

3.3 MECHANICAL HEAT GENERATION

Where friction occurs, mechanical energy is changed into heat. Usually one tries to avoid this effect, because it means losses of energy. If, however, heat is required, this can be a very effective and easy way to generate heat.

The mechanical energy can be produced by either a wind- or waterturbine. It is interesting to note, that a heat generator in conjunction with a windturbine is an ideal match, since both machines have a similar 'power to speed' characteristic.

The principle of converting mechanical energy directly into heat through friction, is applied in the heat generator: If a medium, such as air, water or oil is stirred, friction, in the form of eddies, will occur and the medium will heat up. In this way the mechanical energy needed for stirring will be changed into heat. With the help of the medium, this heat can be moved to the place where it is needed.

3.4 ECONOMIC CONSIDERATIONS: THE HEAT GENERATOR COMPARED WITH OTHER ENERGY SOURCES

It is not possible to give solid facts about the economy of the heat generator operation here. Too much depends on the local situation and the costs of alternative heat energy sources.

For practical purposes however, one may look at the specific situation in Nepal where many turbine mills exist to which a heat generator could be attached. These mills operate different agro-processing machines and spare capacity is often available that could be utilized to run a heat generator. A calculation of the specific economies of the heat generator operation must therefore consider only an appropriate portion of the investment which went into the turbine installation.

A calculation of the return on investment can not be done at this point since this would be subject to the actual income achieved in the end-use of heat energy generated. However, a comparison of the operating costs of generating heat energy by different methods will reveal whether it is preferrable to use a heat generator rather than an alternative. As basis for comparison, systems producing 10 kw of useful energy will be taken.

Electricity generated by a small turbine may be ruled out as a competitor right at the outset because of its rather exorbitant level of investment and slightly higher maintenance costs in comparison to a heat generator. The use of fuel oil, firewood, mains electricity and bio-gas may be considered as an alternative.

3.4.1 COMMON COST FACTORS

Independent of the end-use of heat energy, labour costs may be assumed approximately equal in different methods of heat generation and must therefore not be taken into consideration. Operating costs then consist of capital interest, depreciation, maintenance costs and fuel costs where required. The total will determine unit costs of useful energy produced, if the efficiency of heat generation is taken into account. Uniform cost rates will be used for capital interest, depreciation and maintenance even though the life time and maintenance requirements may not be exactly the same for all systems. In the Nepalese context, we shall consider the following costs:

CAPITAL INTEREST: Loans obtainable for development activities are at 14% interest. An adjustment must be made for inflation to calculate real costs. The result is a real rate of interest of 5.5%:

$$\text{Real rate of interest } i = \frac{(100+p)}{(100+a)} * 100 - 100$$

where: p = bank's rate of interest (14%)
       a = inflation (8%)

DEPRECIATION: A working life of the equipment of 10 years is assumed and linear depreciation is considered, i.e. a rate of 10%.

MAINTENANCE: Neglecting labour costs, the expenses for material and spare parts are assumed at 3.5% of the investment per year.

3.4.2 SYSTEM SPECIFIC COSTS

TURBINE DRIVEN HEAT GENERATOR: According to the outline given earlier, 30% of the turbine-mill installation costs is taken into account. The average costs of a 15 kw turbine mill have been computed [19] at US$ 6,300. 30% of this amounts to US$ 2,100. To this we have to add the actual cost of the heat generator installation of US$ 800 including ducts and a drying bin. Total investment is therefore US$ 2,900. The overall efficiency of heat generation and use is taken at 75%.

FUEL OIL: A relativly simple atmospheric burner is assumed to cost US$ 1,200 including air ducts, a drying bin and a chimney for self-induced draft. Fuel costs are US$ 0.45 per liter [20]. Overall efficiency is taken at 50%.

FIREWOOD: A low-cost furnace and drying bin are assumed to cost US$ 200, working with an overall efficiency of 20%. The price of firewood varies extremly from place to place, depending mainly on the degree of deforestation. One has to consider that fuelwood prices reflect only the collecting- and transporting costs and not the cost caused by the fast depletion of Nepal's forests. In 1981 the government price for firewood was 0.054 US$ per kg [20].

MAINS ELECTRICITY: Electric heating elements and a motor driven fan are assumed to cost US$ 300.-, including air ducts and a drying bin. Where available, the unit cost of electricity will be US$ 0.07 per kwh. The system would work at an overall efficiency of 70%.

BIO GAS: Assuming a system efficiency of 60% in the conversion of biogas into useful heat, a biogas plant with a capacity of approx. 500 cft. gas production per day will be required. Based on cost figures from Nepal [21], such a plant, including the drying equipment, would cost US$ 3,600.-. It is assumed that no operating costs arise, implying that the fertilizer value equals labour costs of biogas plant operation. The actually required 3,050 cbm of biogas can be produced with the plant in question at a utilisation rate of about 65%, which is realistic.

3.4.3 COST COMPARISON

The following table shows a computation of fixed and variable costs for the different heat generating systems. Taking 1,000 operating hours per year, equivalent to the turbine driven heat generator system capacity, unit costs at a yearly production rate of 10,000 kwh low/medium temperature end-use energy, are calculated.

COST COMPARISON OF DIFFERENT HEAT ENERGY SYSTEMS: operating costs for 10'000 kWh end-use energy											
Energy System	Invest-ment costs [$]	Fixed costs fc		Fuel heat value [kcal]	Effici-ency [%]	Quan-tity of fuel	Fuel unit price [$]	Varia-ble costs [US $]	Total opera-ting costs [US $/ yr.]	Costs per unit [¢/ kWh]	Ranking
		[%]	[$/ yr.]								
	I			q	eta	Q	fp	vc	yc	c	
Turbine/Heat Generator	2900	19	551	-	75	-	-	-	551	5,5	1
Fuel oil	1200	19	228	8000 /l	50	2150 liter	0.45 /l	967	1195	11,9	5
Firewood	200	19	38	3000 /kg	20	14330 kg	0.05 /kg	716	754	7,5	3
Mains electricity	300	19	57	-	70	14286 kWh	0.07 /kWh	1000	1057	10,6	4
Biogas	3600	19	684	4700 /m3	60	3050 m3	-	-	684	6,8	2

For a first approximation it is sufficient to produce a table as shown above. Calculations were done using the following formulae of general validity:

FIXED COSTS:

$$fc = (i+d+m) * I$$

where: i = real rate of interest
d = rate of depreciation
m = maintenance cost
I = investment costs

VARIABLE COSTS:

$$vc = Q * fp$$

where: Q = quantity of fuel
fp = fuel unit price

QUANTITY OF FUEL:

$$Q = \frac{t * p}{q * eta}$$

where: t = yearly operating hours
p = plant capacity
q = specif. heat value
eta = overall conversion efficiency

YEARLY OPERATING COSTS:

$$yc = fc + vc$$

COST PER UNIT:

$$c = (t * p) / yc$$

3.4.4 CONCLUSION

Where the potential exists, the heat generator system gives the best economic performance under the circumstances considered. Biogas seems quite attractive and may be of interest especially where plant costs are still lower. In the Nepalese hills the relatively cool climate however, clearly makes it a less attractive solution, because the system performance may be severely affected during several months of the year.

The use of firewood ranks third in terms of unit costs of energy. It must be pointed out here that the regenerative capacity of a good forest in the hills is about 5 tons per year. The relatively small operation would therefore require a forest area of three hectares or the establishment of an energy plantation which would incur additional costs, and would probably better reflect firewood costs with a higher

price. Because of low capital involvement, the wood fired plant would incur practically the same unit costs even if utilization of the plant's capacity is only 50%, while in that case, unit costs for the heat generator operation would double. A heat generator system of 15 kw output on the other hand, would incur practically the same investment cost, resulting in a lower unit price of energy, while for a larger wood fired plant unit costs would remain the same.

Operation of a heat generating plant with fuel oil or mains electricity is far from being competitive with the heat generator in the Nepalese context. Elsewhere, these alternatives may be competitive, if fuel oil/electricity costs are about one third of the rates given.

One may conclude from this, that wherever small hydropower potentials exist, the heat generator may well be a serious contender in economic operation compared to other sources of heat energy.

4.0 THE HEAT GENERATOR

FIG.6:   THE HEAT GENERATOR (LEFT) WITH PIPES CONVEYING THE HOT
AIR TO THE KETTLE (RIGHT).

4.1 THE HEAT TRANSFER MEDIUM

The choice of the heat transporting medium depends mainly on circumstances. The following table shows some advantages and disadvantages of a few of them.

medium	advantage	disadvantage
air	no cost, small sealing problems, high temperatures possible	low specific weight, low heat transfer coefficient makes equipment bulky
water	low cost, high specific weight, high heattransfer coeff	low boiling point, for temperatures >80 degr. pressurisation neccessary, water treatment important, corrosion problems
thermo-oil	high boiling point no need for pressurisation, high specific weight and heat transfer coeff	high cost, oxidation problem therefore closed system needed, thermal expansion, sealing problems

Work done on the heat generator centered around the processes "drying" and "boiling". The first application of the heat generator for a boiling process was planned for soap- and paper making. It involved a 80 ltr kettle to contain the soap or pulp. The paper making process involves both, boiling and drying. Therefore a solution was looked for where both applications are possible.

Air seemed to be the right transporting medium for these applications. The difficulty in developing this solution was to overcome the problems resulting from the low heat transfer coefficient of air. A heat generator churning water or oil seemed to be: too difficult to seal and too expensive and

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complicated. This led to the decision to use air as transporting medium. The solution utilizes a specially designed kettle, where the air has enough contact area to transfer its heat.

With the experience in using this design, it can be safely said that this approach apears to be correct for most applications. One disadvantage however became evident: The shape of the kettle can not be choosen freely, since the necessary fins can economically only be welded to straight walls. This is a disadvantage in applying the heat generator to processes where the shape of the kettle can not easily be changed. For example in distilleries and cheese dairies a spherical shaped copper vat is used. This shape cannot be changed without influencing the accepted method of processing. Secondly, to exchange existing vats is expensive and therefore, it is unlikely that a new heating method is applied in established factories, if it is not possible to keep the vat as it is and just heat it up with pipes built into the vat and containing the heating medium. This would necessitate a liquid medium like oil or water, or even better steam. This area is one subject of phase II of the heat generator project.

4.2 THE DESIGN PRINCIPLE OF THE HEAT GENERATOR

In principle the heat generator is a fan with a housing,
which creates eddies.   FIG.7 shows the basic layout of the
machine
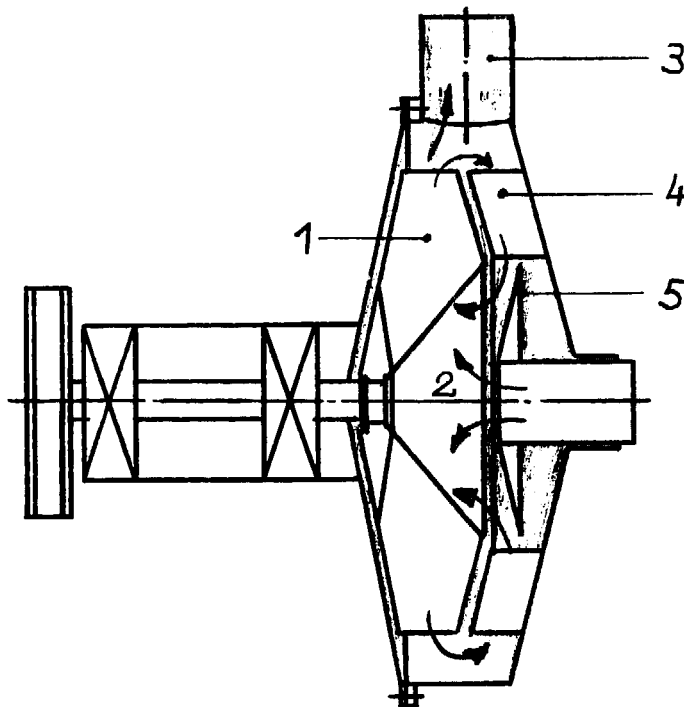
FIG.7: THE HEAT GENERATOR

Air is drawn in by the runner (1) through the inlet (2) and
part of it leaves the housing through the outletpipe (3), the
other part flows over the baffels (4) which are arranged
radially.   The abrupt change in direction causes eddies which
create friction of the air molecules, thus heat is generated.
The hot air passes the valve (5), mixes with cold air coming
in through the inlet (2), and is drawn in again by the runner.
The amount of air leaving the generator and its temperature is
dependent mainly on the position of the valve (5). When it is
in closed position, the generator is simply a fan blowing air

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at ambient temperature. If the valve is fully open, nearly
all of the air leaving the fan is drawn over the baffles (4),
thereby being heated up to the maximum temperature. Between
those two extremes, all temperatures can be obtained by the
infinitely variable valve.

4.3 THE KETTLE

The consumer of the heat produced, is the kettle. It is
designed to hold a volume of 80 ltr, with a valve at the
bottom to discharge its contents. The applications of soap-
and paper making require that there be no obstruction in the
kettle itself, which is the reason for the fins on the
outside.

The problem in designing the kettle is to get the heat of
the air into the liquid fast enough. The following formula
describes the factors involved in this problem:

```
*******************************
*                             *
*   Q = ALPHA * A * DEL.T     *
*                             *
*******************************
```

where: Q   = Heat flow   [kcal/h]
       ALPHA = heat transfer coefficient [kcal/(h*degr*sqrm)]
       A   = Surface of heat transfer [sqrm]
       DEL.T = Temperature difference   [degr]

According to this formula, there are three factors involved
which influence heat transfer:

1. Alpha: this coefficient is dependent on the medium and
    its velocity. If air passes the kettle wall very fast,
    alpha is high and with it the transfer rate. In our case

the relation is:

$$ALPHA = 6.14 * \text{air velocity}[m/s]^{0.78}$$

This states, that ALPHA is almost proportional to the air velocity i.e the velocity should be kept at a maximum.

The value of ALPHA for air to the steel wall is roughly 60 to 80, with air velocities between 20 and 25 m/s. The value for the transfer from the wall into the liquid is about 2,000. Which means that the limiting factor is the transfer from the air to the wall of the kettle.

2. Surface : heat transfer is proportional to the surface the air is in contact with. Therefore the surface of the outside wall is increased by fins to make up for the lower ALPHA of this side of the transfer.

3. Temperature difference: Since the temperature of the liquid is fixed at boiling point, it can be said that the higher the temperature of the air the higher the heat flow.

In order to make use of this, fins were welded to the outside wall of the kettle in such a way that the surface of the fins is maximum but the area for the air to flow through is a minimum in order to keep air velocity high. With decreasing distance between the fins, pressure loss over the fins, and manufacturing costs, increase. This sets a limit to attempts to enlarge the contact area. The result of computer aided optimising are the Z-shaped fins. Fin- and kettle size

are chosen carefully and can not be changed without influencing the efficiency of the whole system!

4.4 PERFORMANCE

Some theory is necessary to understand the performance of this heat generator-kettle system.

1. Basically, the heat generator is a blower. Therefore, the laws of fan design apply here as well. In this connecton only one formula is important:

```
************************
*                      *
*              3   5   *
*   P = c * N * D      *
*                      *
************************
```

where: P= power to run machine
                         c= a constant factor
                         N= rotational speed
                         D= outside diameter of the runner

This means: the power, necessarry to run the machine increases with the

- third power of the speed of the runner ie. if the rpm is doubled, the power increases eight fold (2 to the power of 3 = 8).

- fifth power of the runner diameter, ie. if the diameter is doubled the power increases 32 fold (2 to the power of 5 = 32).

It has been asked frequently whether the heat generator could be made smaller in diameter for smaller driving powers. This question can be answered by applying the above formula: If the diameter is decreased only by a small portion the driving power decreases very rapidly, ie. with the fifth root. It is more advantageous to lower the already quite high speed in order to obtain smaller driving powers. This reduces problems caused by vibration and noise. It is also important to keep the step up ratio between turbine and machine as small as possible, which again asks for lower rotational speeds.

The above formula is only correct as long as the air in the generator remains at the same temperature. With an increase in temperature, the specific weight of the air decreases, the air becomes "lighter" and the power necessary to move it becomes smaller.

2. If connected, heat generator and kettle influence each other. It is important to understand this relation, when talking about temperatures. For a given speed, the generator takes a certain amount of power. This energy changes into heat- and kinetic energy and can leave the generator only as a combination of air temperature and -velocity. The rate at which this heat energy will be transferred into the liquid of the kettle depends largely on the air temperature. As long as there is less heat transferred than produced by the heat generator, the temperature will rise. It will rise until heat "used up" by the kettle is equal to the heat produced. This means

at the same time that a higher power input into the heat generator means a higher temperature level of the air, resulting in a higher heat transfer into the kettle.

3. If a fan has to blow against a backpressure, its driving power decreases. If the valve of the generator is closed, a backpressure builds up in the housing and the driving power becomes less. As mentioned above, the temperature also has to fall. In this way the heat input into the kettle can be regulated between certain limits.

These relations are shown in FIG.8. Here an example how to use this graph: If a turbine can deliver 10 kw at full gate opening the belt drive to the heat generator should be such that the generator runs at 1770 rpm. At this, the generator-kettle system takes 10 kw. If the system should take less power at the same speed, the valve can be closed, thereby decreasing the driving power down to 3.8 kw. This can be necessary for example if a second machine has to be run from the turbine or if less water is available in the dry season. In this way the heat generator can be adjusted easily to use excess power and lends itself readily to integration into a system of machines driven by the same turbine.
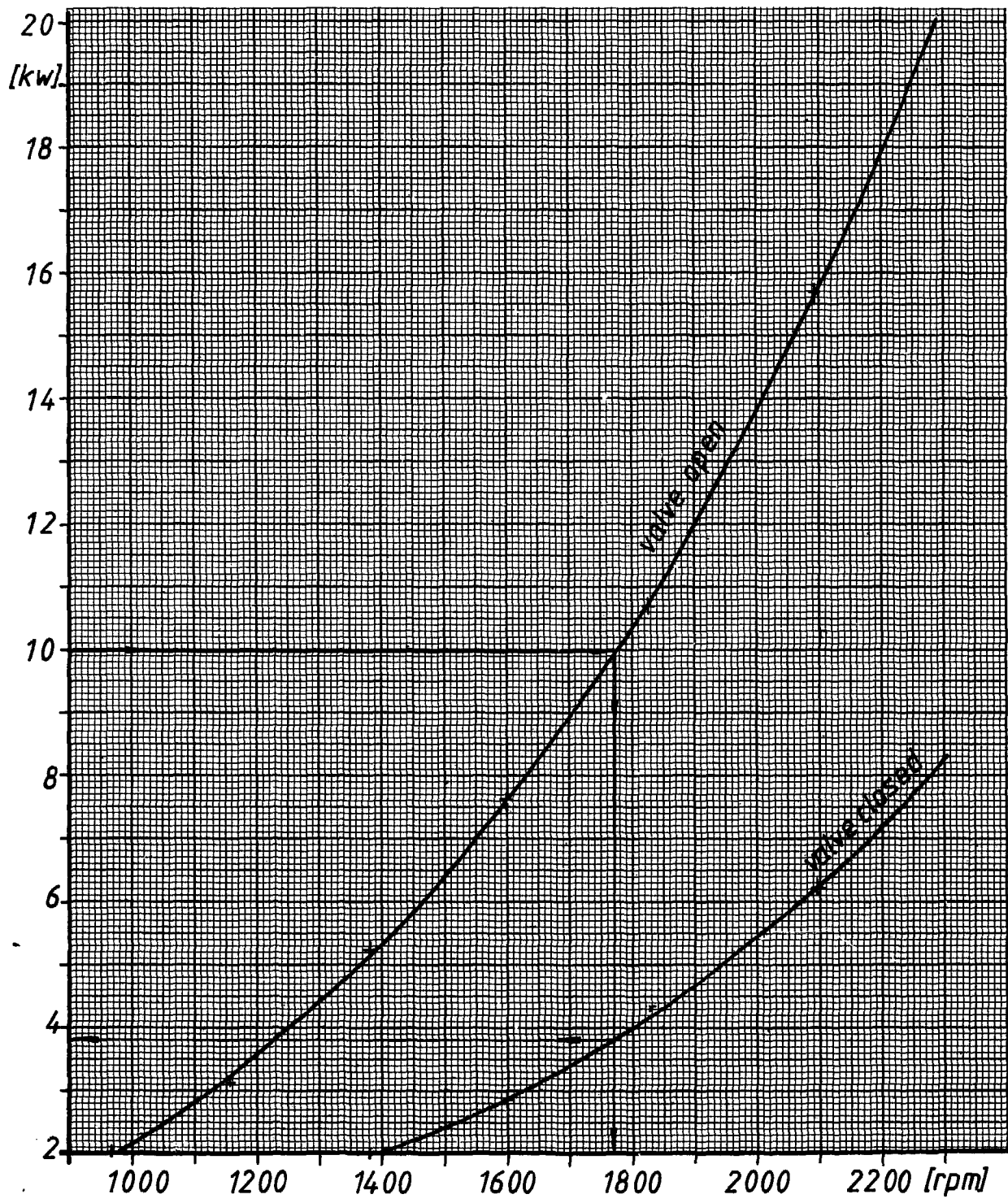
FIG.8: PERFORMANCE OF HEAT GENERATOR-KETTLE SYSTEM

4. The efficiency of the whole system depends mainly on two
    factors: the quality of the insulation against heat
    losses, and how air tight the system is.   The system
    tested in Furtwangen was insulated with 50 mm mineral
    wool. This resulted in an overall efficiency of 0.76,
    i.e.   24% of the energy was lost through the insulation.
    Of course any type of insulation can be used, as long as
    it can stand temperatures of 250 degr.C.

    In this connection it is important to note, that the
    temperature will rise considerably higher, when there is
    no liquid in the kettle. When using organic insulation,
    this fact has to be considered!

    The system has air tight ducts. The only air leak is
    where the shaft of the runner enters the housing.
    However, this leakage was found to be insignificant.   Air
    tight joints and ducts have a significant influence on
    efficiency. This can be explained by the fact, that air
    of 200 degr.C has a relativly high heat value compared to
    air at ambient temperature. Thus, even small losses of
    air through leaks, result in a significant drop in
    efficiency.

5.0 THE MANUFACTURING PROCESS

This section deals only with some difficulties which have been experienced during the production in Nepal. Most problems arise during assembly, where not all steps can be given in the drawings. This chapter will describe the steps of assembly following the production of the individual parts.

5.1 BALANCING THE RUNNER

The runner is revolving at relativly high speed and vibration problems will result, if not enough care is taken to eliminate imbalance. During welding of the runner, it is extremly important to keep the seams equally long on opposite sides.
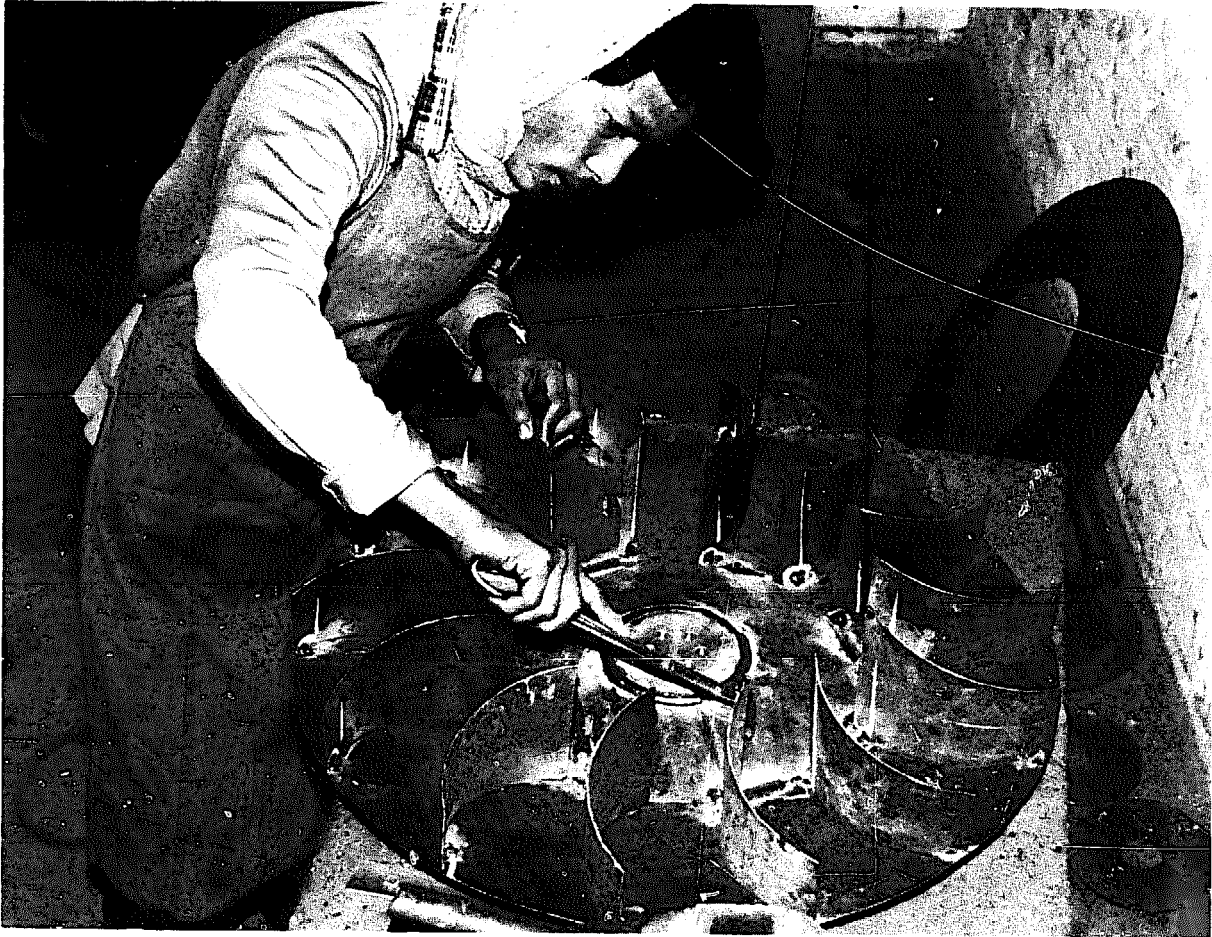
FIG.9: WELDING THE RUNNER.
Note: Here the hub was welded first to the cones which
resulted later on in distortion and consequently imbalance
problems!

The following welding procedure of the runner (drawing
07/00)avoids problems of distortion and imbalance:

1. Bolt the bearings to the stand (01/00);

2. Insert the shaft and check with a square that shaft is at
    right angle to the stand. This unit is shown in FIG.10:
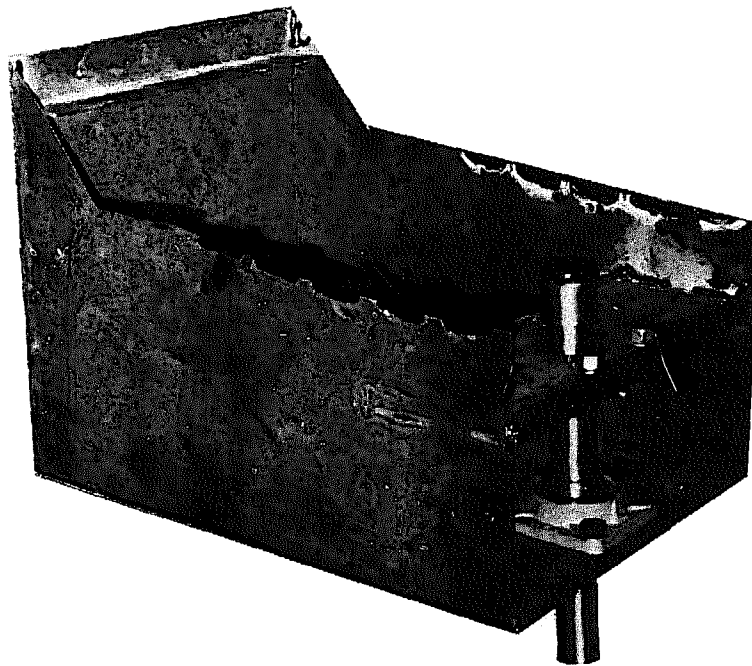
FIG.10: STAND AND SHAFT ASSEMBLED.
Note: Stand is of previous design where "teeth" are cut
out to reduce heat transfer from generator housing to the
stand. This has been made easier by welding pieces of
flat iron to the housing as described later.

3.   Insert runner hub (07/01) into cone (20/02) and weld cone

     (20/04) to previous cone. Weld runner blades (07/03) to

     (20/02), taking care that beads are equally long and that

     blades are positioned accurately (balance!). Weld cone

     (20/03) to the blades.

4. bolt the runner hub (07/01) to the shaft.

5. Put the finished runner on the hub and tack while checking whether this assembly runs true. Any deviation smaller than 5 mm plus/minus on the outside diameter can be tolerated.

6. After final welding, the runner needs careful static balancing. For this, the assembly of runner, shaft and pulley i.e. all rotating parts, are placed on two dead levelled edges. These can be part of a small jig of two machined pieces of angle iron on stands, or the bed of a lathe (check level first!). The assembly is left alone on these edges and the unit will stop rolling as soon as the point of imbalance comes to the lowest point. Radially opposite of this, a piece of equal weight of the imbalance has to be welded. The assembly is checked again, until the unit does not start rolling by itself anymore. This process is time consuming but very important, especially if the generator is to run at high speed.

5.2   ASSEMBLING THE HEAT GENERATOR

Put shaft-runner assembly into housing (08/00), and clamp both together with C-clamps. This will ensure that runner and housing will be aligned to each other. Insert the shaft of this unit into the bearings until the cone of the housing touches the stand. In this position, the 6 flat iron pieces are welded to housing and stand. The C-clamps can be removed.The runner is now positioned with a 5mm gap between housing and runner.

Inlet pipe (13/00) is inserted into cover (11/00), the valve (14/00) and handle (15/00) assembled, and flange (17/01) bolted to cover, with seal (9/00) inbetween. Flange (17/01) will be welded after the final assembly of the whole system. After bolting the cover to housing with seal (09/00) inbetween, check that runner is not touching while rotating, otherwise move the shaft axially in the bearings.

5.3   ASSEMBLING THE KETTLE

While welding the fins to the kettle make sure that the gap between the separate fins is kept to the minimum. The idea of the z-shaped fins is to form two air ducts, the one guiding the hot air first up along the kettle wall, and after reversing, down again through the outer duct, thereby having intimate contact with both the kettle wall and the fins. Any big gap between the seperate fins will result in a shortcut between the two ducts, thereby reducing the efficiency of heat transfer.

Also, care should be taken to keep measurement 15 mm in the kettle drawing (18/00) as accurate as possible, in order to let cone (20/07) fit nicely into the step formed by the fins, so that not too much air will short cut at this point.
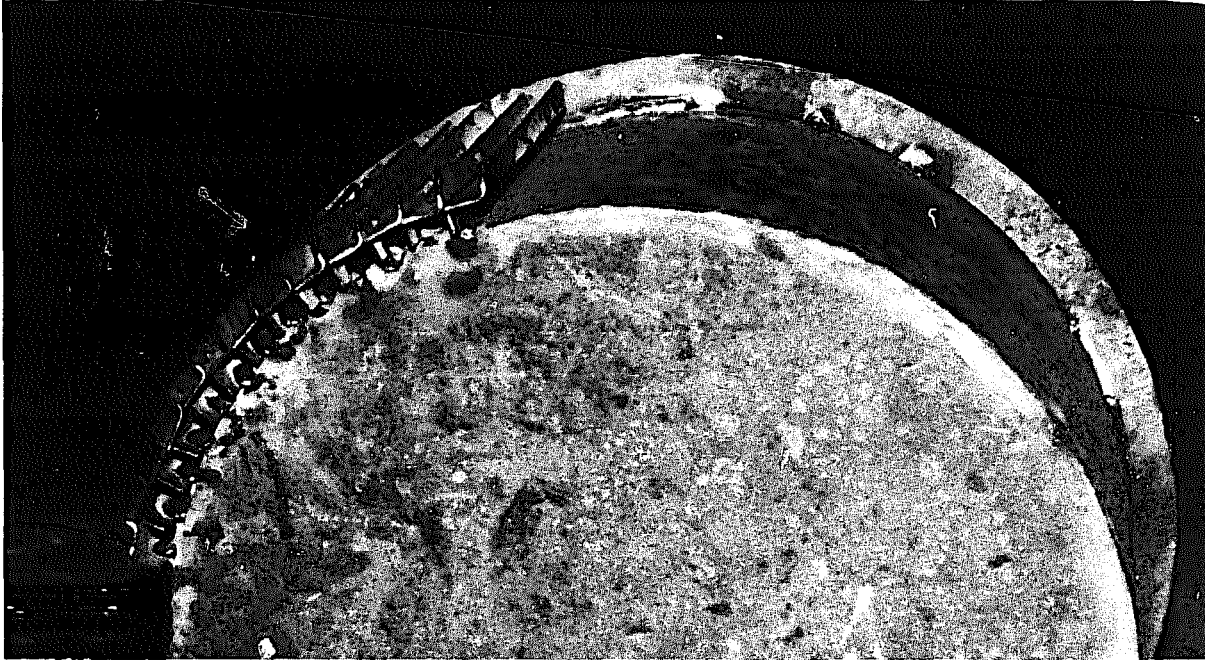
FIG.11: WELDING THE FINS TO THE KETTLE WALL

To weld the kettle housing (17/00) follow this procedure:

1. Bolt flange to the kettle flange and put the kettle upside down on the floor.

2. Weld pipe sections together, put cone (20/08) on pipe (23/03) and weld cone (20/07) to it. Put these parts in place, so that cone (20/07) rests in reset formed by the fins.

3. Weld jacket to flange, then cone (20/08) to jacket and pipe.

4. Pipe secton (23/01) is carefully aligned and welded to cone (20/08)

5. The hole for discharge pipe (16/00) is marked and cut out.

The parts will look simmilar to FIG.12:
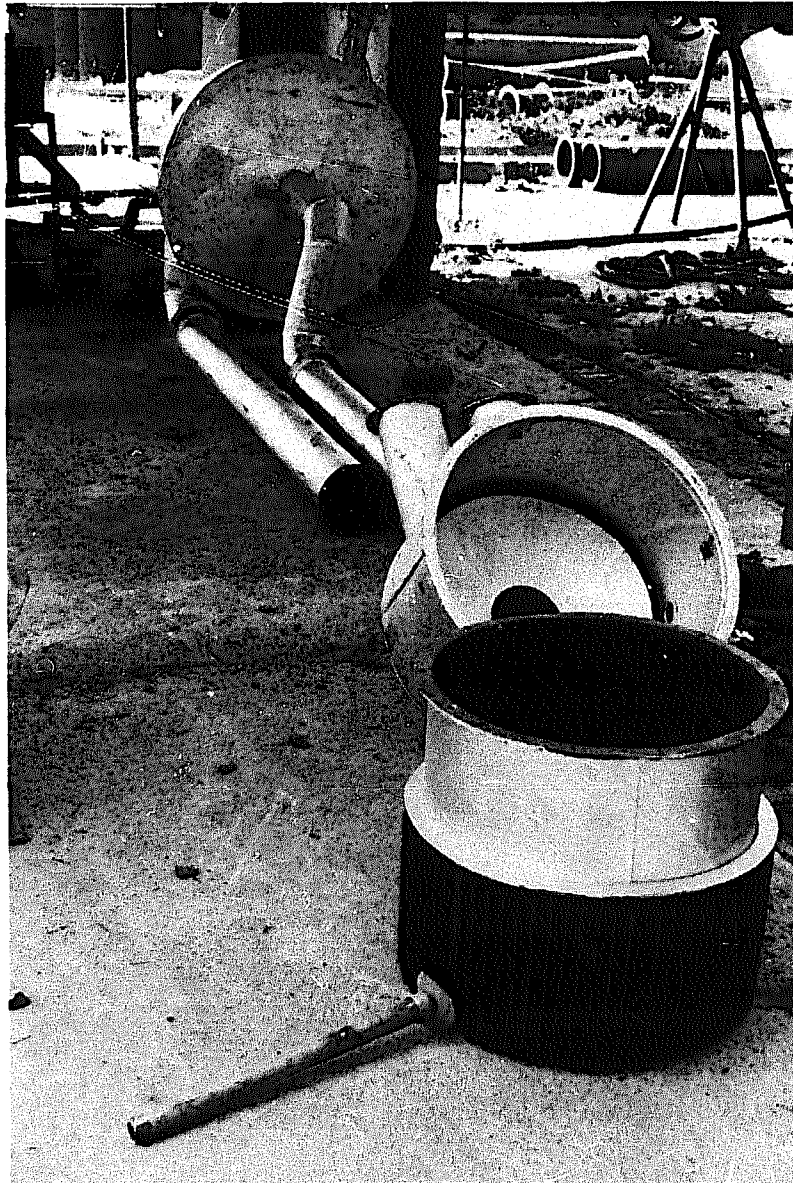
FIG.12: PARTS READY FOR FINAL ASSEMBLY
Note: FIG.12 shows the demonstration unit in Nepal. Changes in design have been done since then in omitting the two separate pipes between generator and kettle, and in changing the flanges of the kettle itself.

5.4 FINAL ASSEMBLY

For the final assembly follow this procedure:

1. Align heat generator with turbine and tighten foundation bolts.

2. Put kettle housing in place so that the generator's outlet pipe (23/05), pipe (19/00) and the kettle's inlet pipe (23/04) align.

3. Align generator's inlet pipe (13/00) with kettle's outlet pipe (23/02). (13/00) should be inserted 25 mm into generator's cover (11/00).

4. Bolt together all pipe flanges (17/01) and weld flanges to the pipes.

5. Insert kettle into kettle housing, fix discharge pipe (16/00) and tighten its nut. Its cone will then seal any air leak between housing and pipe.

6. Run heat generator and check for any air leak at the flanges.

5.5 INSULATING THE SYSTEM

At this stage, the system needs to be insulated against heat losses. The easiest is to cover all surfaces with 50 to 100 mm thick mineral wool. Since this material was not available in Nepal, a different solution was used:

Around the final assembly, a brick wall was built and the whole space gained was filled with ricehusk. This is a very cheap but effective insulation material. Tests in Nepal proved this method of insulating as nearly as effective as mineral wool.
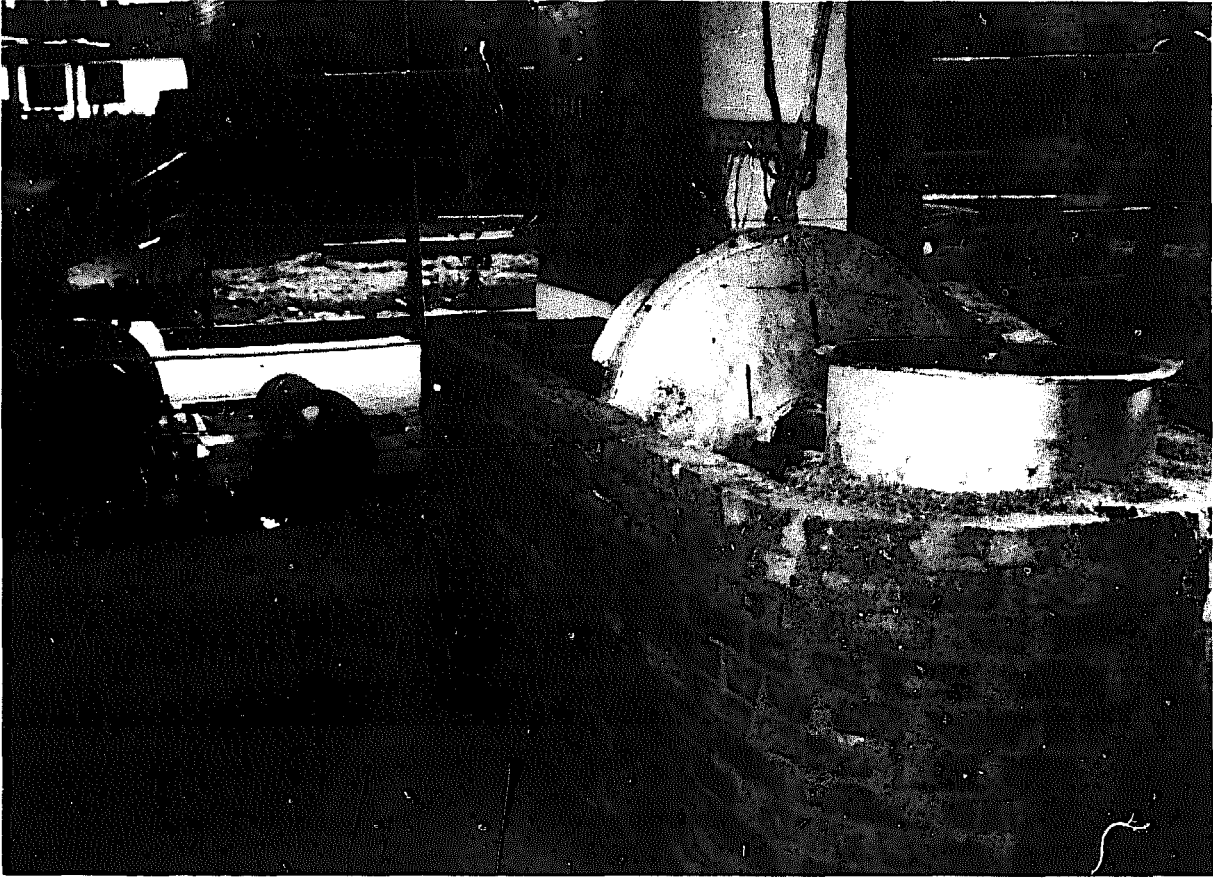
FIG.13: THE PLANT READY TO RUN!

Another way to reduce heat losses is to insulate the hot generator parts against the cooler ones. This is the reason for the six flat iron pieces welded between stand and housing. The aim is here to reduce contact between these two parts.

Heat will also escape through the shaft, thereby heating up the bearing. To reduce this effect, an insulating disc (07/02), made of asbestos or any other heat resistant material, is introduced between shaft and runner. It must not be ommitted, since heat will shorten the bearing's life! For the same reason the bearings should be regreased every other month.

5.6 THE BELT DRIVE

The belt drive between turbine and heat generator has to convey the driving power and step up the rotational speed. Since turbine speeds, power levels and possible arrangements of the machine are site specific, only a few hints for the design of the drive can be given:

1. Since turbine and heat generator are fixed to the ground the belts have to be tightened by an idler pulley.

2. In most cases a diameter of 170 mm is appropriate for the generator pulley (2/00).

3. The recommended v-belt size is the B-section. With this section, use 3 belts for driving powers under 10kw, 4 belts for 10-15kw and 5 belts for 15-20kw. Only use matched sets of belts!

4. For bigger step up ratios, the angle of contact between the belts and the small pulley gets less than 130 degr. In these cases the bigger pulley needs no grooves and can, therefore, be manufactured much easier in a small workshops.

6.0 POSSIBLE FUTURE DEVELOPMENTS

The heat generator as heat source for dryers has proven its usefullness. It now becomes apparent that it is necessary to find suitable designs for drying cabinets appropriate to Nepal.

The heat generator-kettle system as it stands now, is a solution appropriate to most processes involving boiling. The next step in applying this development would be to find solutions for processes, where the form of the kettle can not easily be changed. This is especially true for cheese making, wool dying and distilling. An appropriate solution seems to be, to incorporate into the housing of the heat generator a steam boiler and convey the steam in heating pipes to the vessel to be heated.

Another area of need for R&D is steam production for processes like parboiling of rice, steaming of seeds prior to pressing and other food processing, where steam is needed directly. Parallel to steam production, it is possible to store small heat quantities in the form of pressurised water. In this way, the heat generator could store energy, as and

when the turbine is not utilised otherwise.

As an example of application of these ideas the inquiry of the Herbs Production and Processing Center can serve to use the heat generator for drying the herbs and heating the still (volume 3 cubic meter). Fig.14 shows, how such a system could look like.
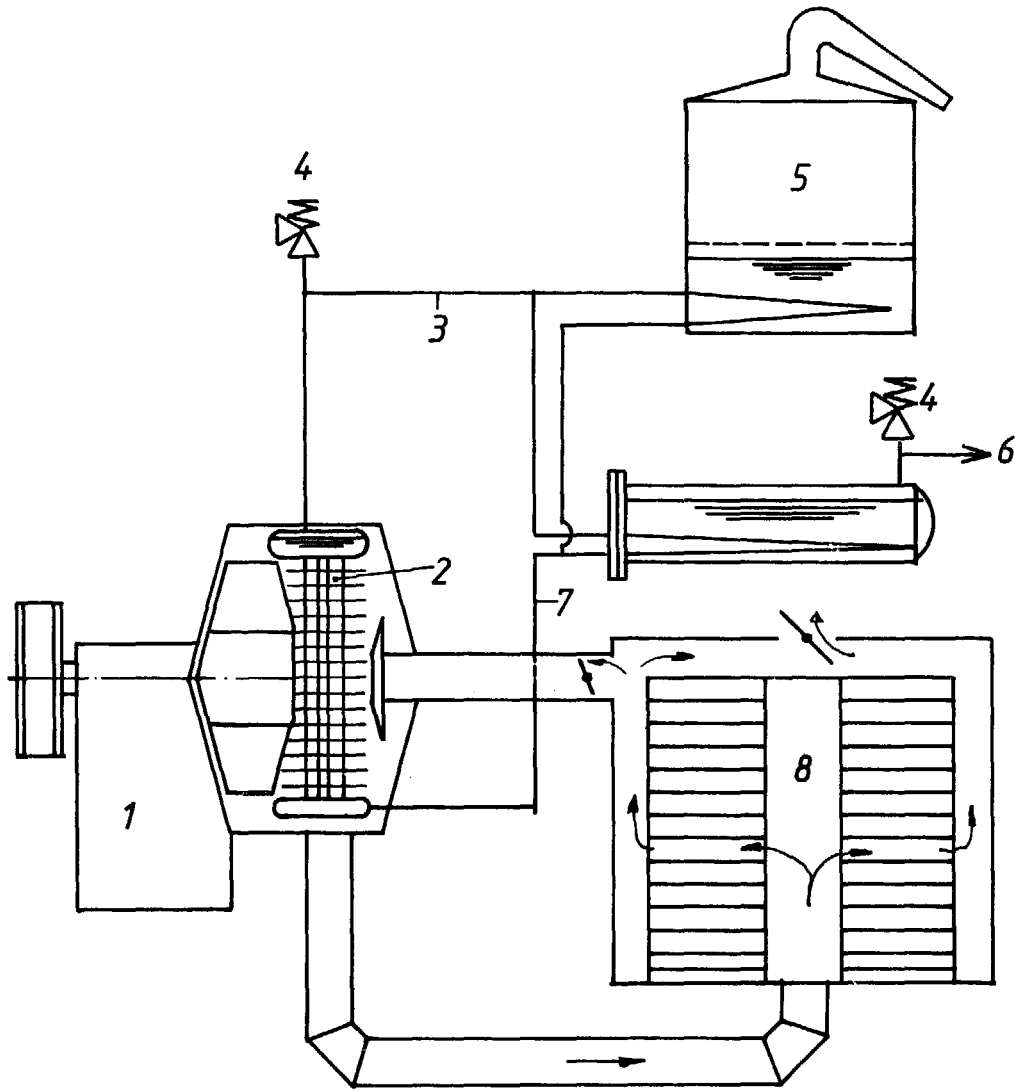
FIG.14: HEAT GENERATOR FOR DRYING AND STEAM PRODUCTION FOR
DISTILLING

1) heat generator   5) still

2) steam boiler   6) available steam

3) steam pipe   7) pipe for condensate

4) safety valve   8) drying cabinet

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APPENDIX

A.1   PART LIST FOR HEAT GENERATOR-KETTLE SYSTEM

NO.	PART NAME	PART NO.	REMARKS
1	HEAT GENERATOR-KETTLE ASSEMBLY	00/00	
1	STAND	01/00	
1	PULLEY ASSEMBLY	02/00	see chapter 5.6
1	RUNNER SHAFT	03/00	
1	BEARING PLATE	04/00	
2	BEARING	05/00	FY 50 FJ (SKF)
1	BEARING PLATE	06/00	
1	RUNNER ASSEMBLY	07/00	
1	HOUSING ASSEMBLY	08/00	
-7 mtr	SEAL	09/00	asbestos string dia.6mm
24	BOLT AND NUT	10/00	M8 x 25
1	COVER ASSEMBLY	11/00	
32	BOLT AND NUT	12/00	M6 x 15
1	INLET PIPE ASSEMBLY	13/00	
1	VALVE	14/00	
1	HANDLE	15/00	
1	DISCHARGE PIPE ASSEMBLY	16/00	
1	KETTLE HOUSING ASSEMBLY	17/00	
1	KETTLE ASSEMBLY	18/00	
1	PIPE SECTION	19/00	

additional drawings:

	CONES	20/00	
	DEVELOPMENT (BENDS)	21/00	
	PIPE SECTION	22/00	
	PIPE SECTION	23/00	

A.2 BILL OF MATERIALS

MATERIAL	SIZE [mm]	AMOUNT	USED IN
Sheet	1.5	2.4 sqm	08/02, 13/01, 13/02, 16/03, 17/00, 22/00, 23/00, 24/00;
Sheet	2	7.0 sqm	01/00, 07/00, 08/01, 11/00 14/00, 18/00, 20/00;
Sheet	3	1.0 sqm	18/00;
Sheet	8	.15 sqm	04/00, 06/00;
flat	3*15	2.2 m	11/00, 17/00;
flat	6*30	12.2 m	01/00, 06/00, 08/03, 17/00;
angle	7*45*45	3.0 m	01/00, 17/00;
cast iron	180∅	.10 m	02/01;
rod	120∅	.06 m	03/00;
rod	65∅	.41 m	07.01;
rod	50∅	.06 m	16/02;
rod	30∅	.40 m	15/00;
rod	8∅	.04 m	16/02;
asbest.plate	3*60*60		07/02;
asbest.string	6∅	7.0 m	09/00;
GI-pipe	1"	.45 m	16/01;
Hex.bolt	M6*15	32 pcs	17/01;
Hex.bolt	M8*25	30 pcs	03/00, 08/03;
Hex.bolt	M12*30	1 pcs	02/00;
Hex.bolt	M14*45	8 pcs	05/00;
Nut	M6	32 pcs	17/01;
Nut	M8	24 pcs	08/03;
Nut	M14	8 pcs	05/00;
Springwasher	6	32 pcs	17/01;
Springwasher	8	30 pcs	03/00, 08/03;
Springwasher	12	1 pcs	02/00;
Springwasher	14	8 pcs	05/00;
key	9*14*75	1 pcs	02/00;

A.3 CONSTRUCTION DRAWINGS (37 NOS.)

M 1:10

M 1:20

A

A

600

550

800

1000

660

78?

1400

1450
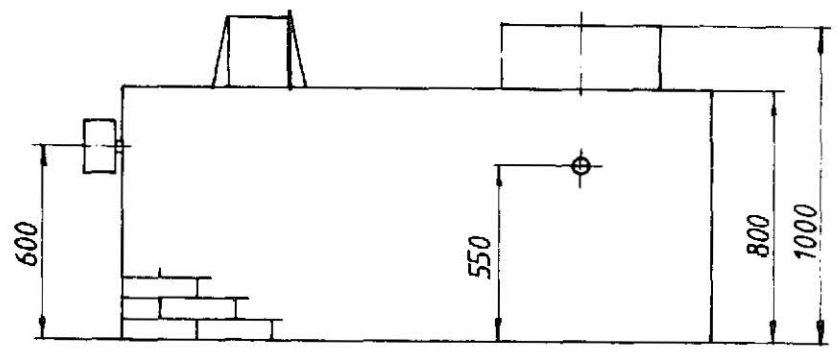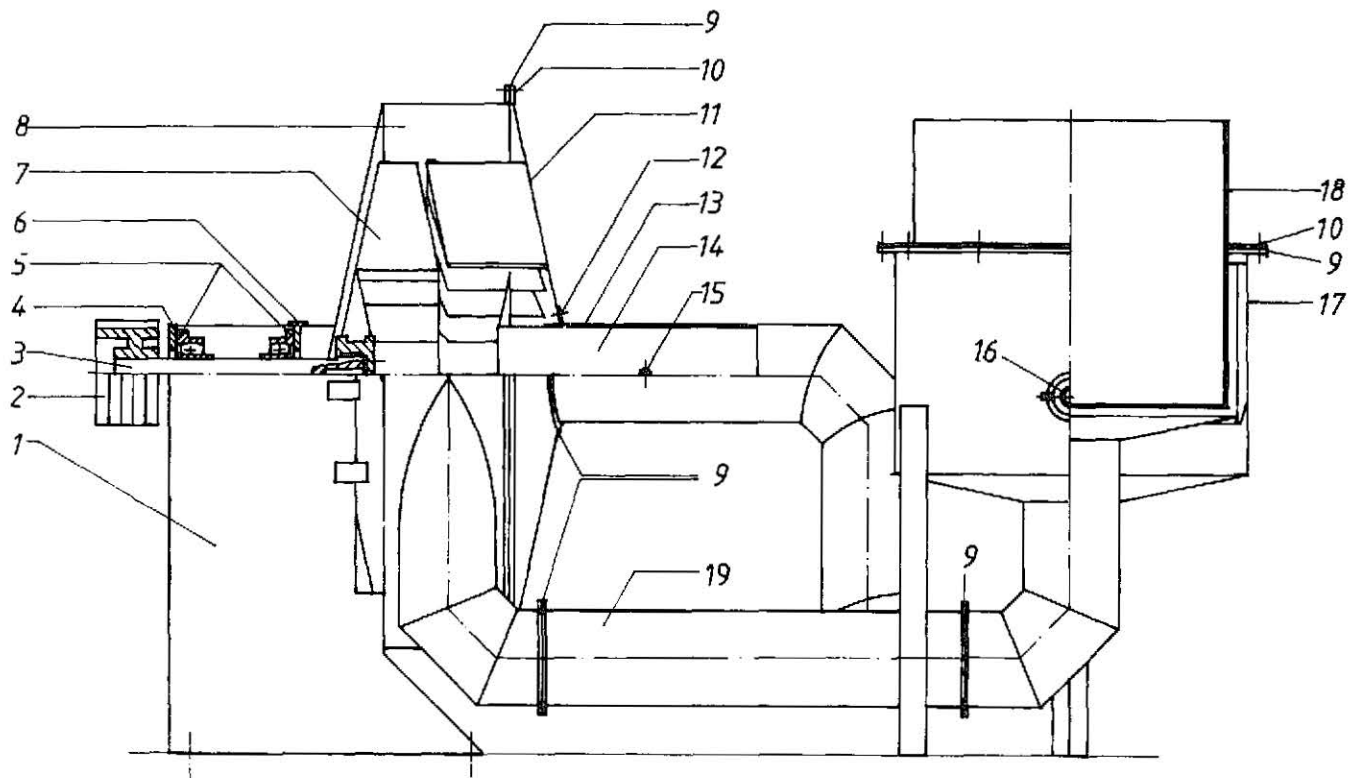
1900
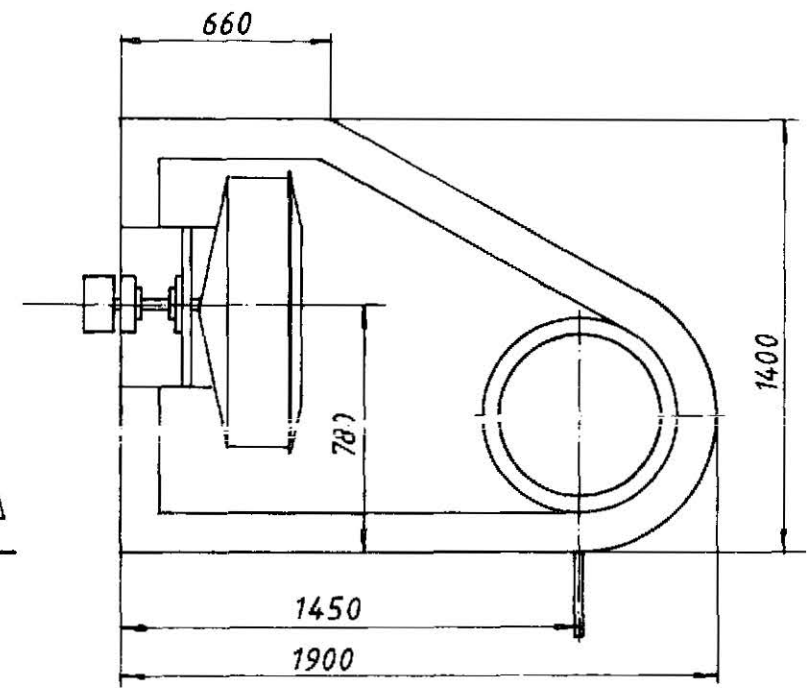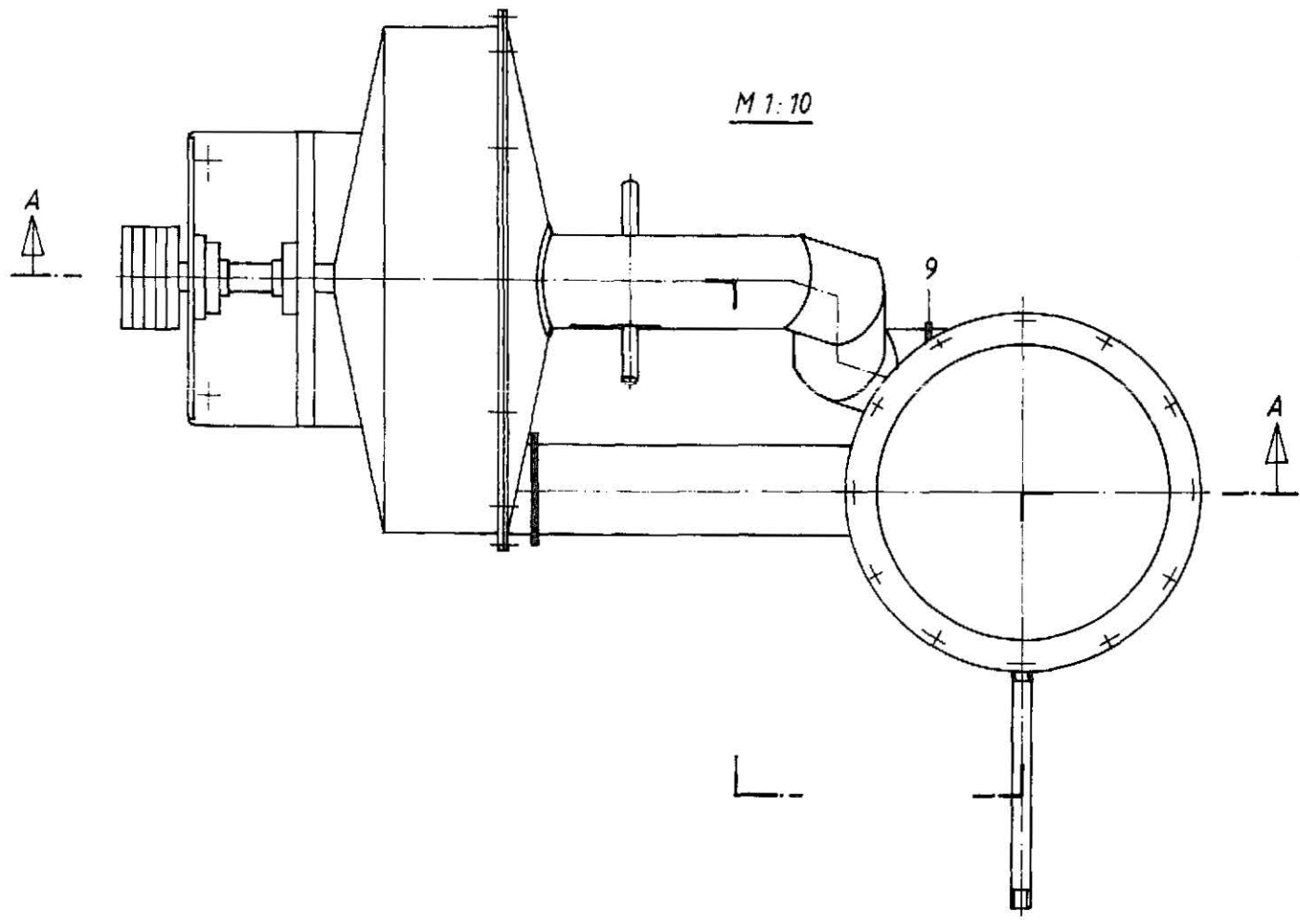
heatgenerator-kettle surrounded by brickwall
holding the insulation (e.g. ricehusk)

| HEATGENERATOR-KETTLE | 00/00 |
| GENERAL ASSEMBLY | |

680

600

A

15   15

70

Φ18

400   500

B   B

bend

section A-A

welded during assembly
of housing

A

04/00

200

300   34.5   500

06/00

155

255

130   430

section B-B

M 1 : 10
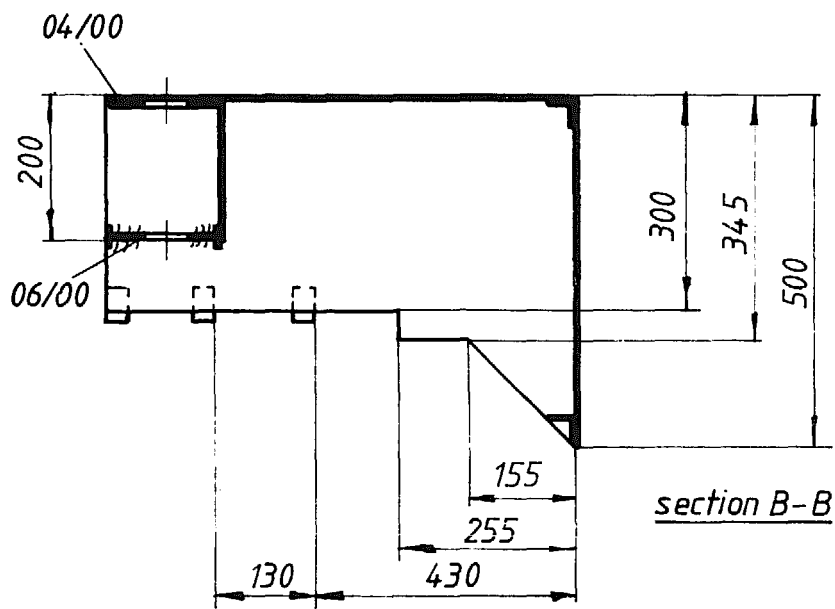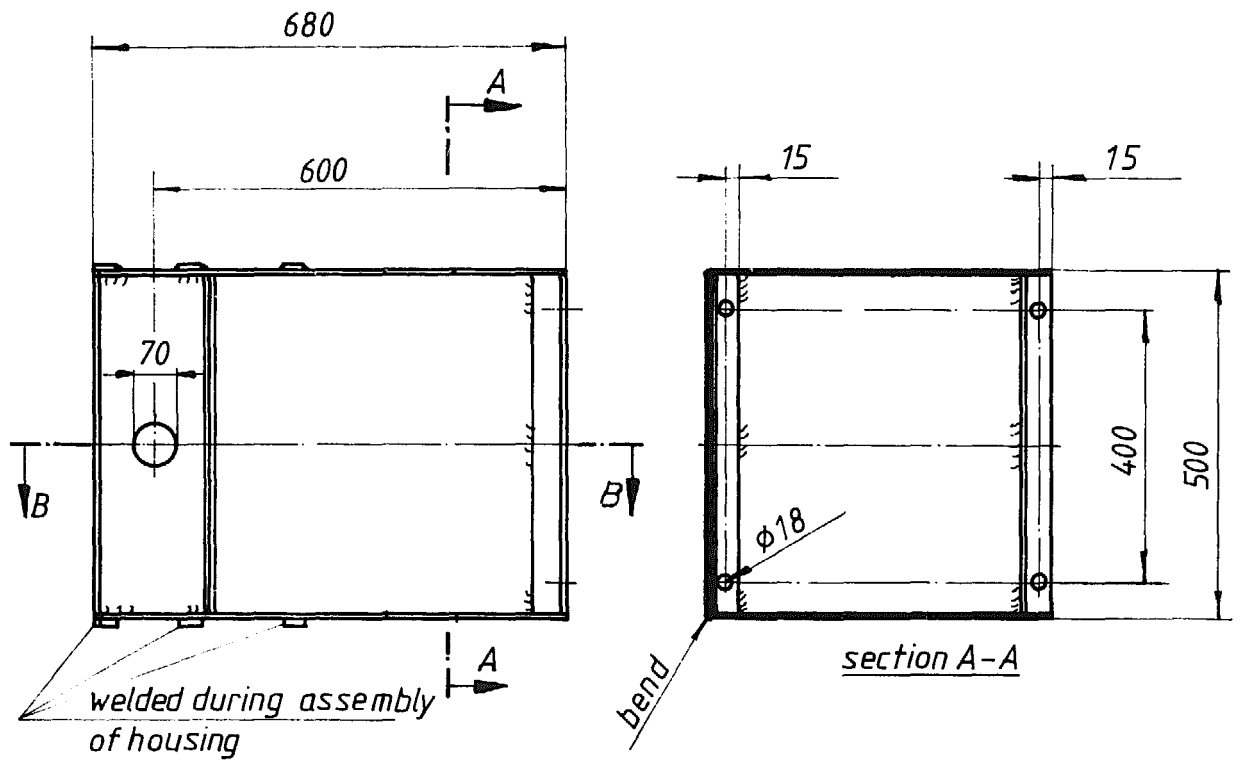
6	flat	6x30x50	Ms
2	angle	7x45x45x500	MS
1	plate	2x200x496	Ms
1	plate	2x500x500	Ms
1	plate	2x680x1500	Ms
1	partno.04/00		
1	partno. 06/00		

STAND

01/00

A 6

02/01

02/02

03/00
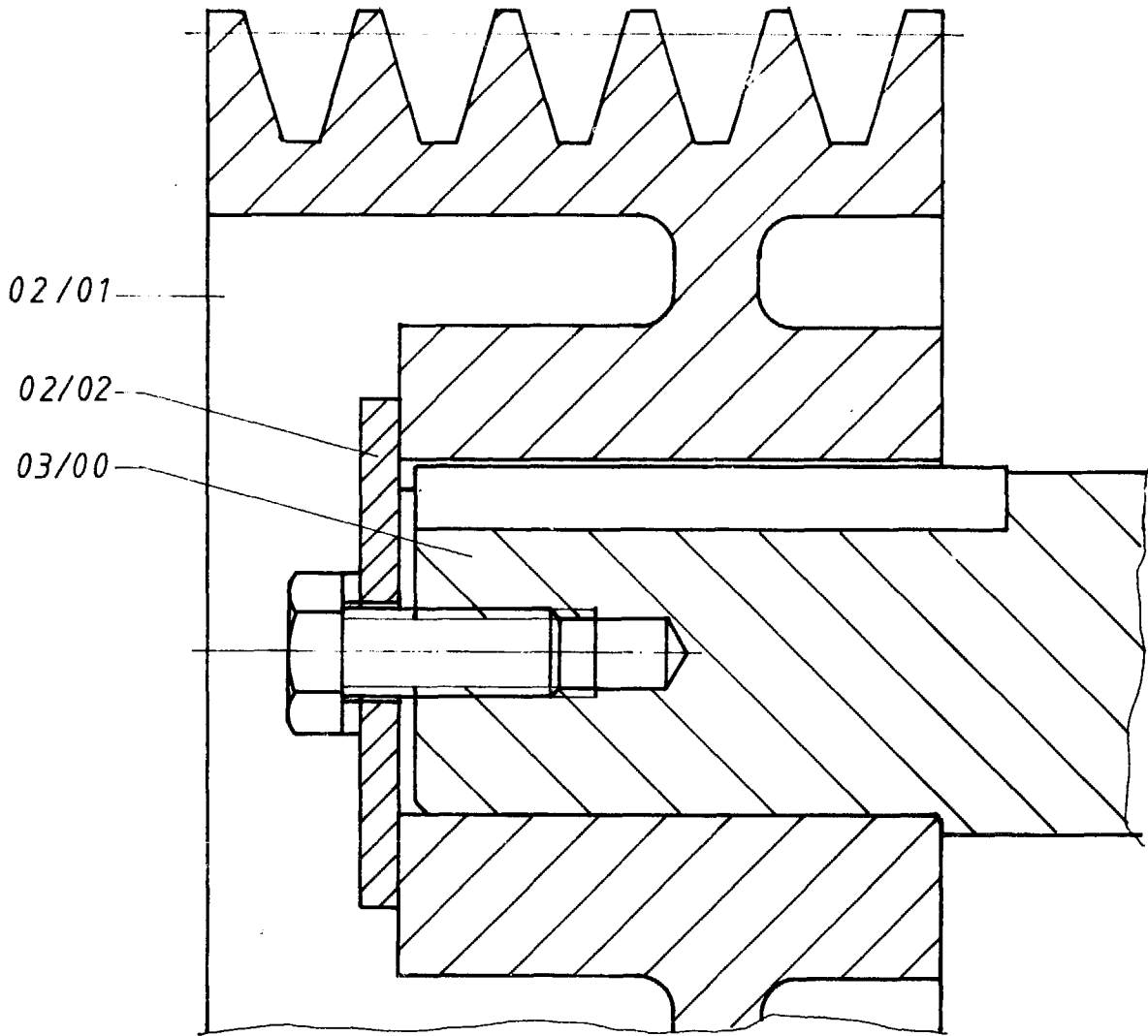
1	hex. bolt	M12×30 with springwasher
1	key	9×14×75
1	disk	02/02
1	pulley	02/01

PULLEY ASSEMBLY

02/00

A7

Ø 177

Ø 120

Ø 90

12,5

(19)

(19)

16

19

L

77

12

19

25

34°

12,5

1,5 × 45°

18

14

$45^{+0,03}$

49
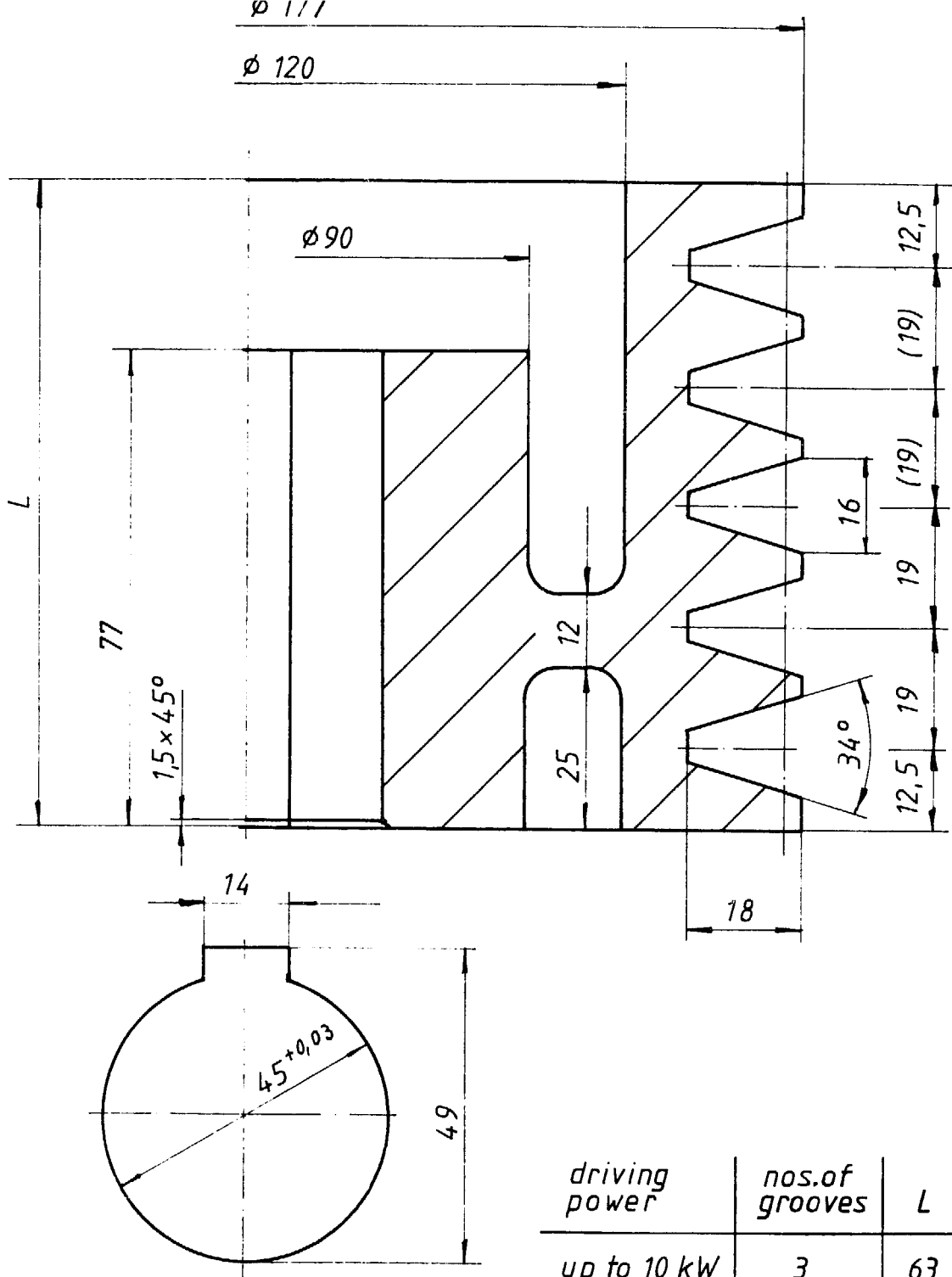
driving power	nos.of grooves	L
up to 10 kW	3	63
10 to 15 kW	4	82
up to 20 kW	5	101

1 castiron   Ø 180

PULLEY

02/01

A 8

6

∅ 70

∅ 14

▽

1 plate   8 × 70 × 70

DISK

02/02

A 9

Ø45 -0,03

M12

2×45°

25

35

14

75

5,5

R2

358

400

Ø50 -0,03

60

25

2×45°

15

Ø25

Ø44   6×M8

Ø59,97 -0,03
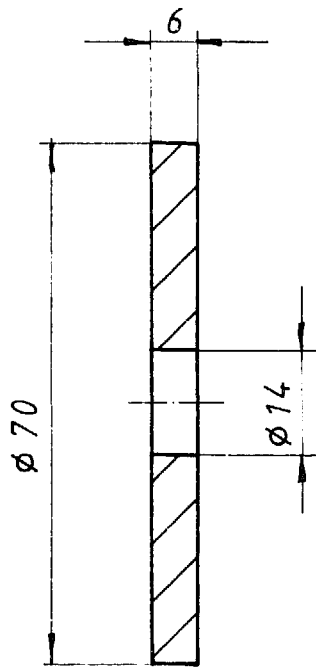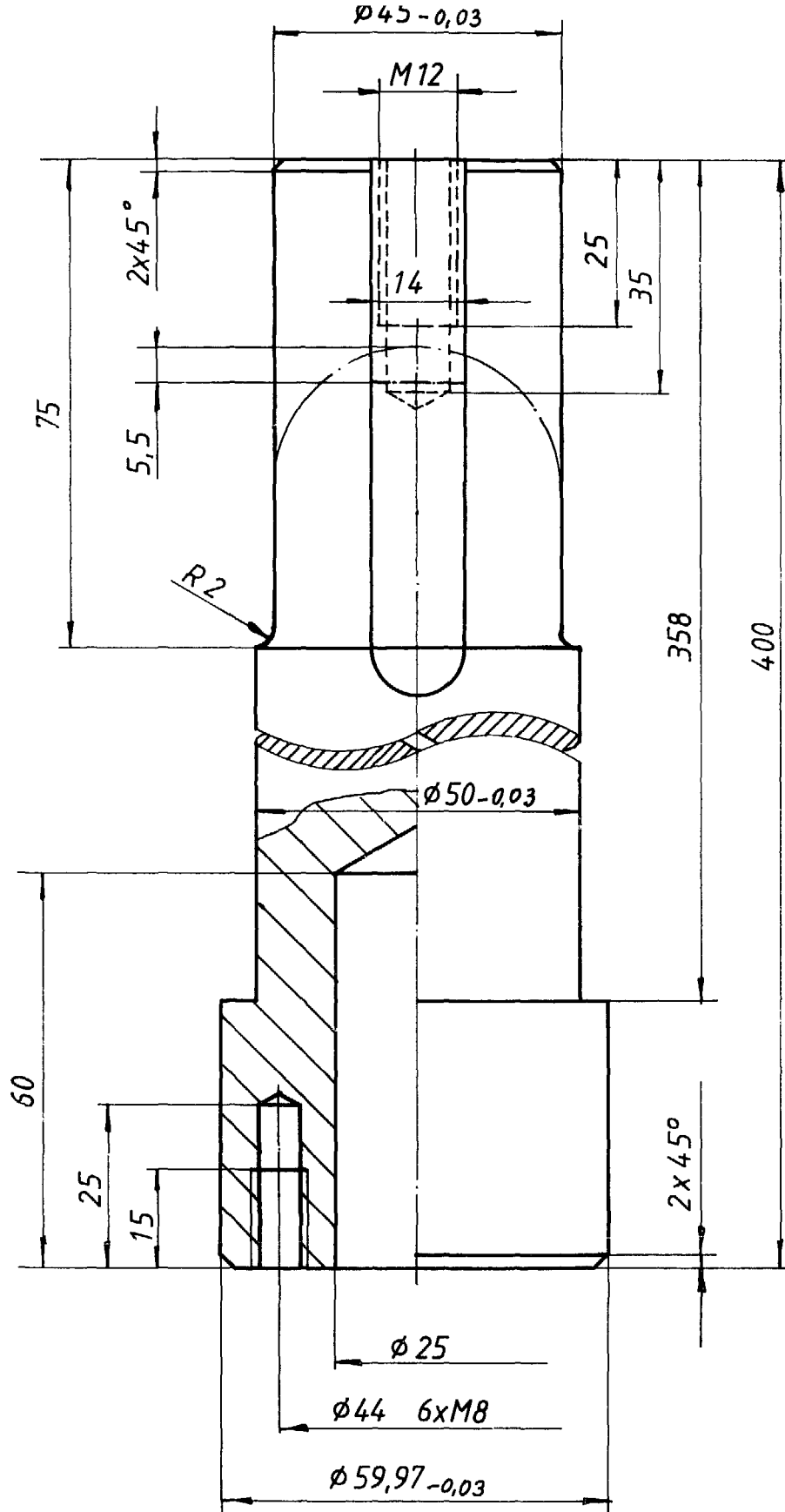
6 hex. bolt M6×25   with springwasher
1 rod   Ø65×405   Ms

RUNNERSHAFT

03/00

A 10

70

111

480

⌀16

111

160
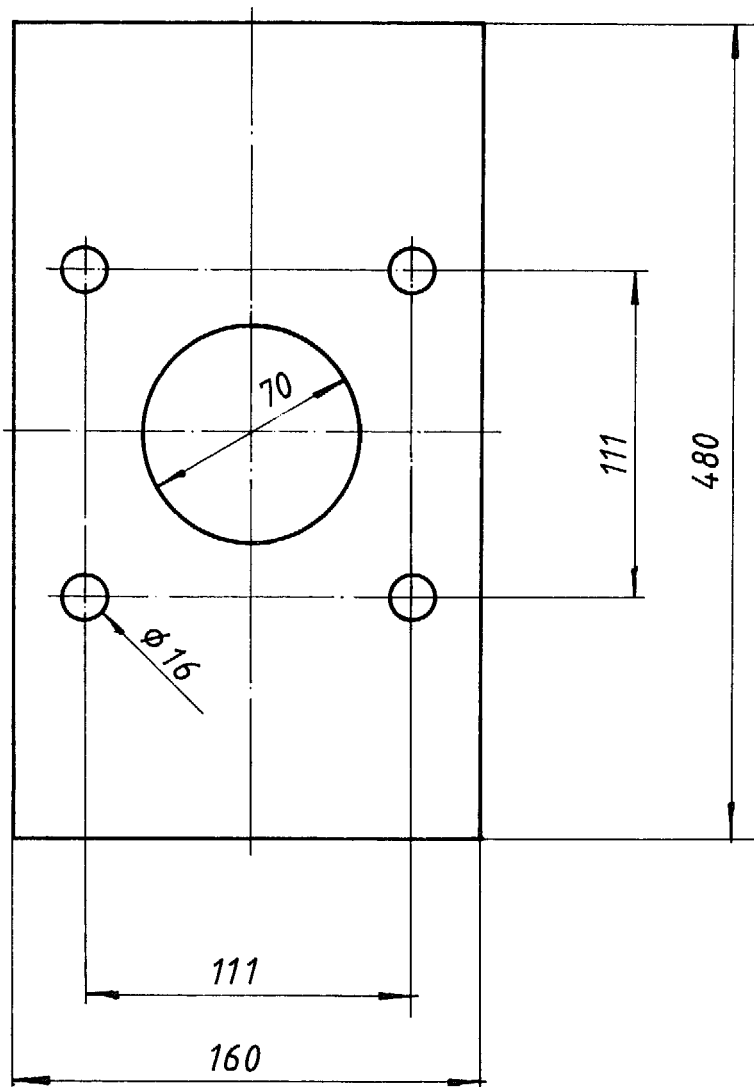
1　sheet　　8x160x480　Ms

BEARINGPLATE

04 / 00

A 11

$\emptyset 50^{H7}$

59

16

111

143

111

143
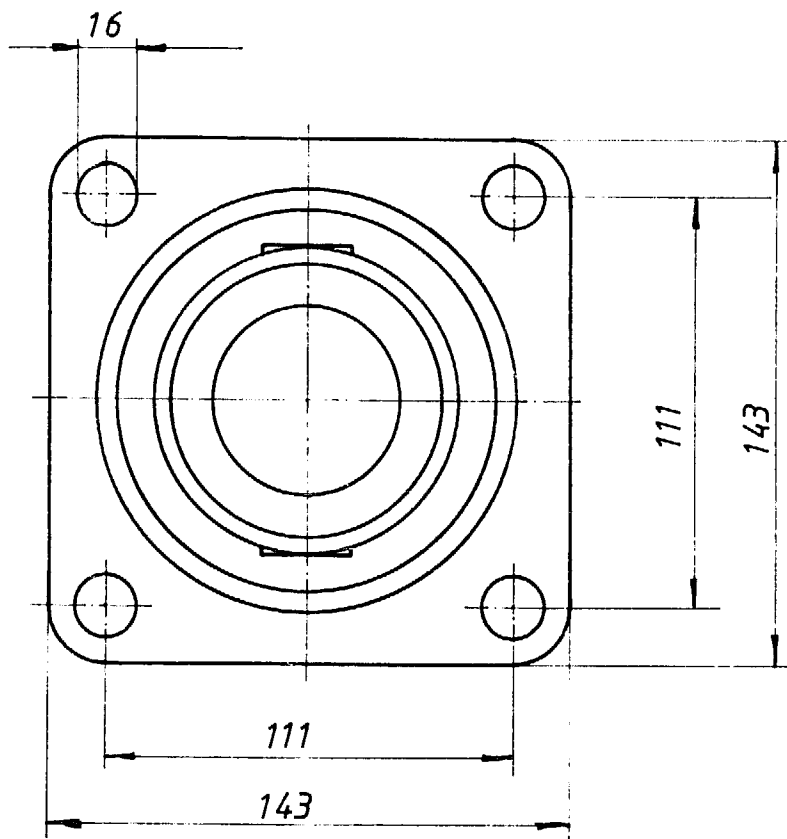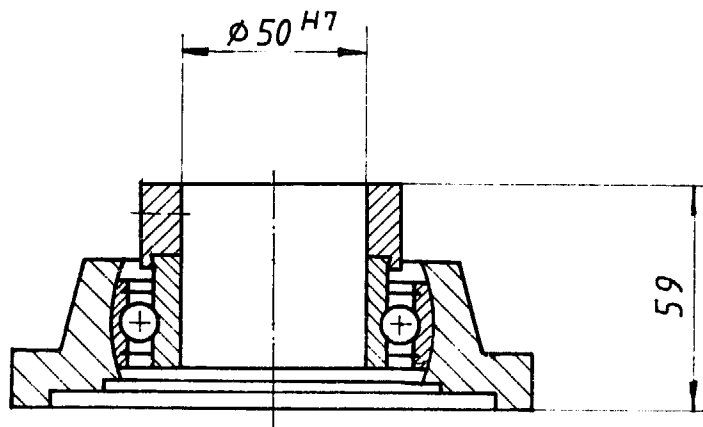
M 1 : 2

1 bearing   FY 50 FJ   (SKF)

BEARING   (2 nos. required)

05/00

A 12

160

8

30

6

∅16

111

160

495

70

111
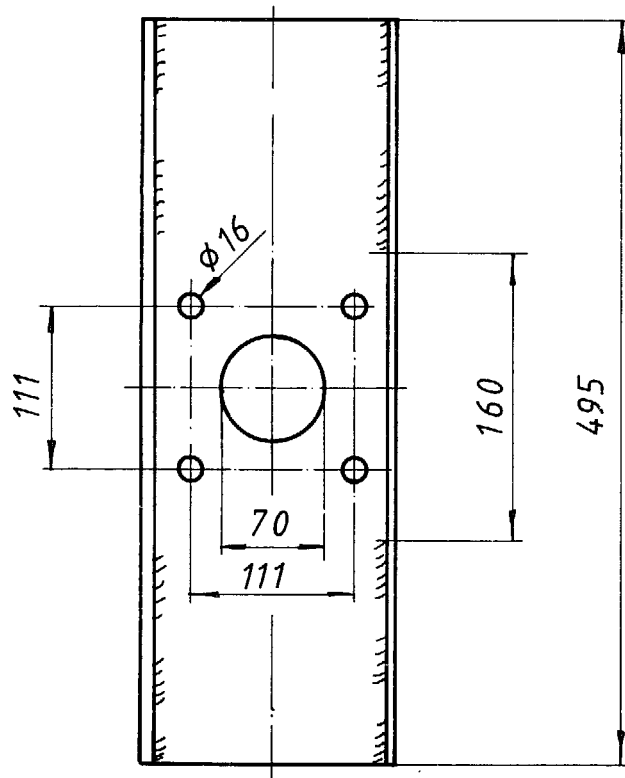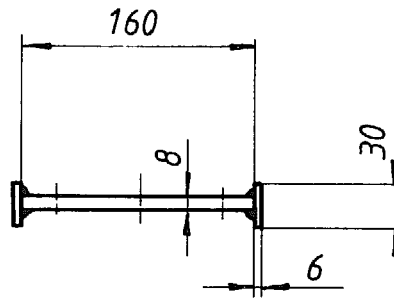
M 1:2,5

2	flat	6×30×495	Ms
1	flat	8×160×495	Ms

BEARING PLATE

06/00

A 13

~149

07/02 — — 07/01
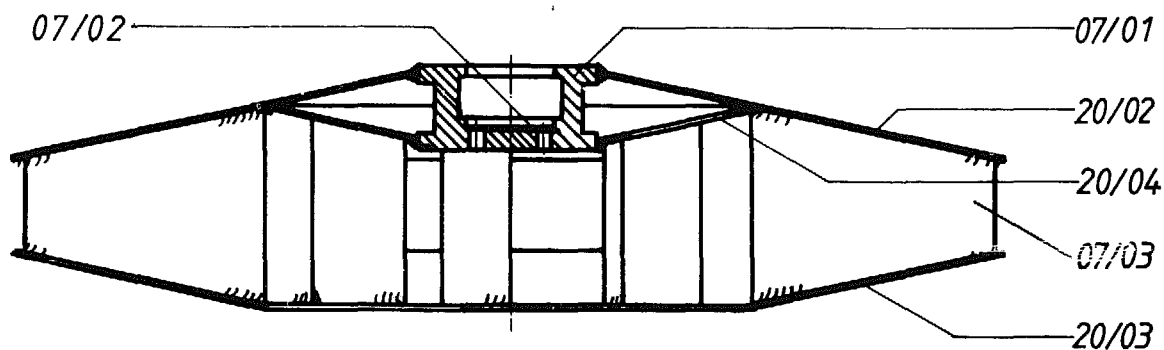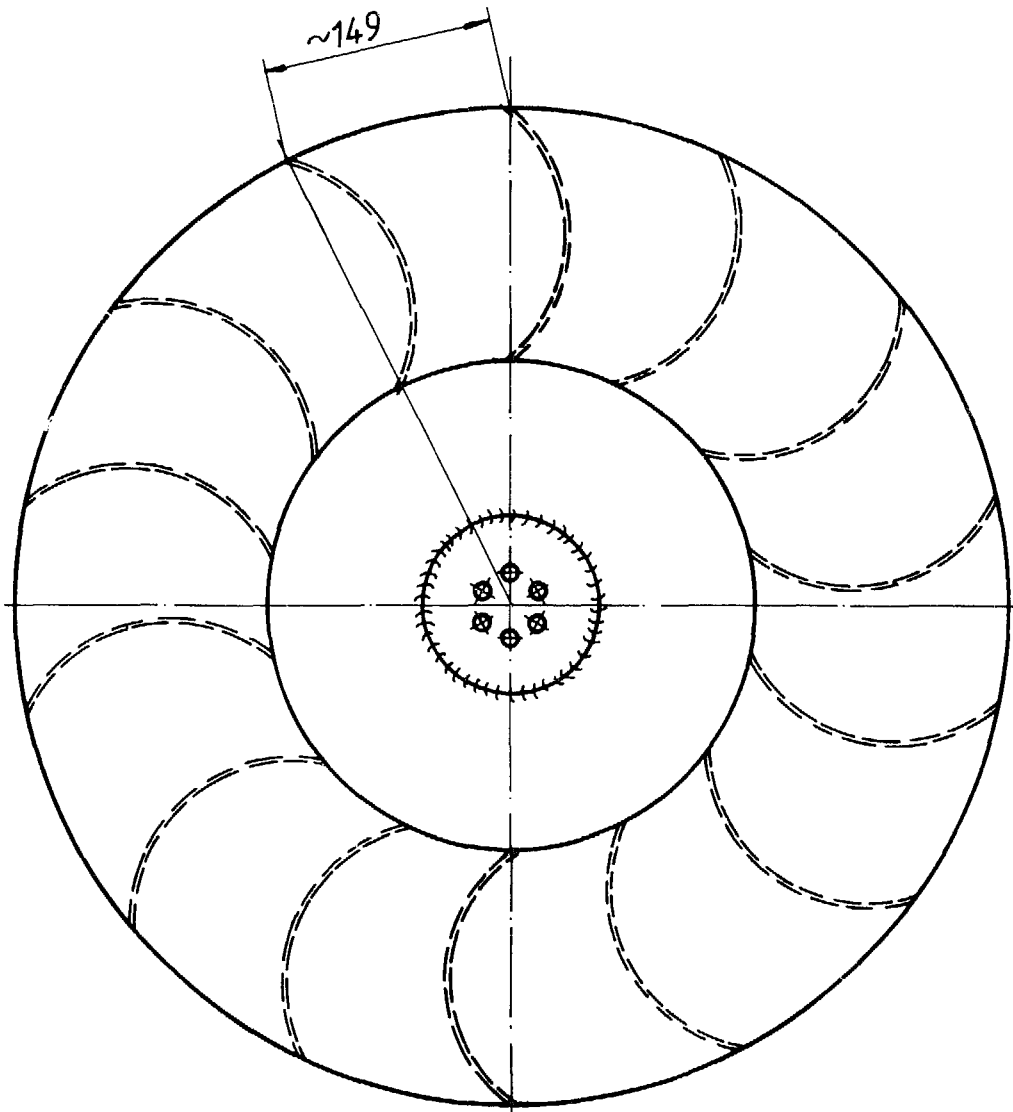
— 20/02

— 20/04

07/03

— 20/03

M1 : 5

1	cone	20/04
1	cone	20/03
1	cone	20/02
14	runner blade	07/03
1	insulation disc	07/02
1	runnerhub	07/01

RUNNER

07/00

A 14

Ø 120

Ø 100

Ø 70

Ø 60 +0,03

7

10

28

35

55

Ø 9

Ø 44 × 6 holes
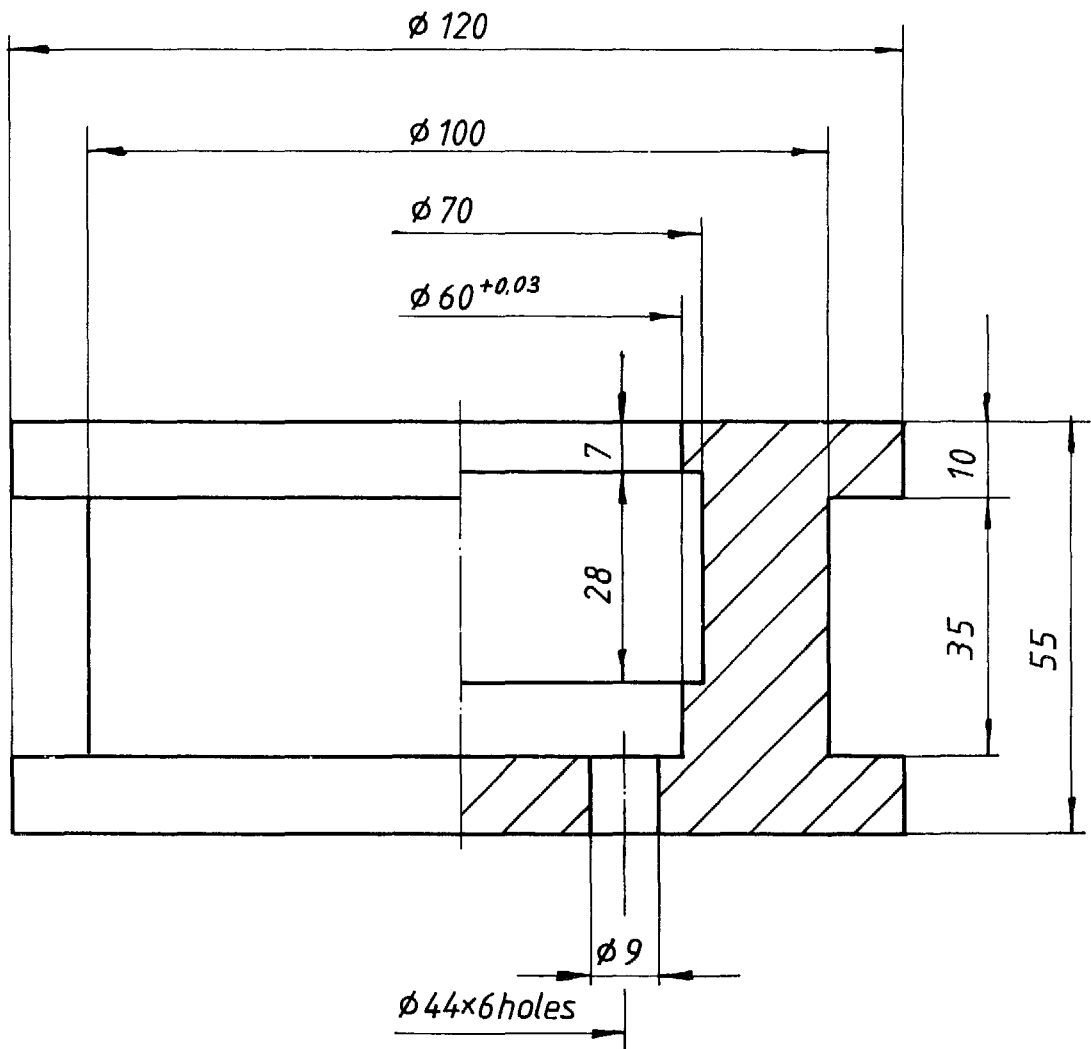
1 rod   Ø 120 × 60   Ms

RUNNERHUB

07/01

A 15

9

thick 3mm

44

60
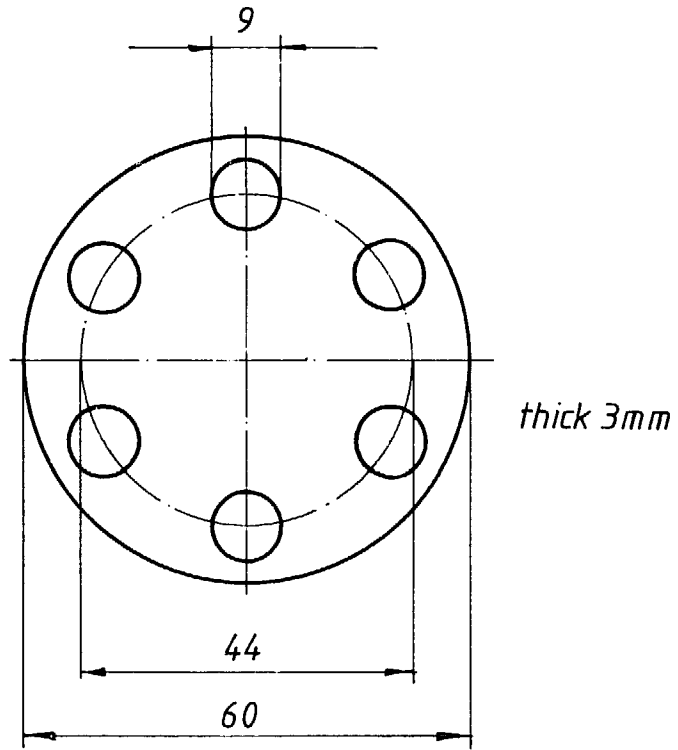
M 1:1

1 asbestos plate   3 x ∅60

INSULATION DISC

07/02

A16

2

R 111

40

170

192

60

38,5

135

development
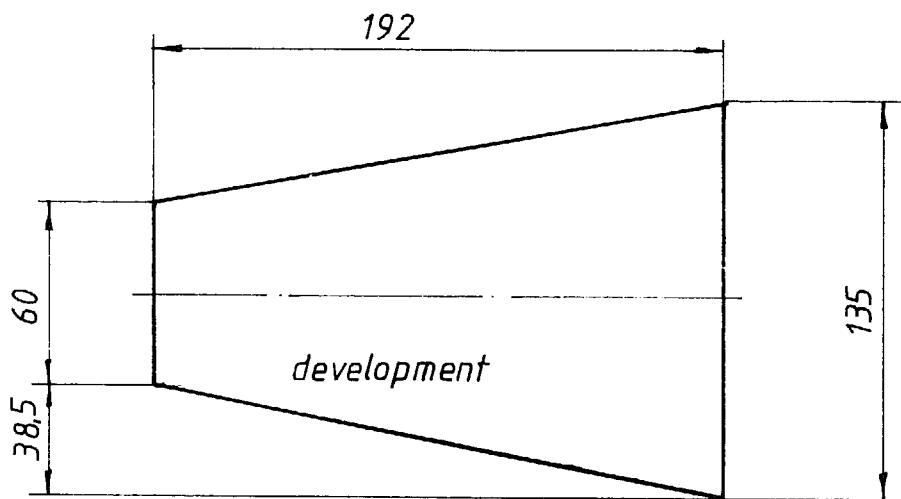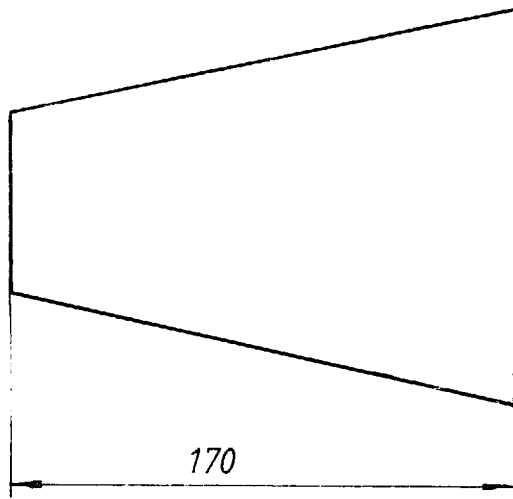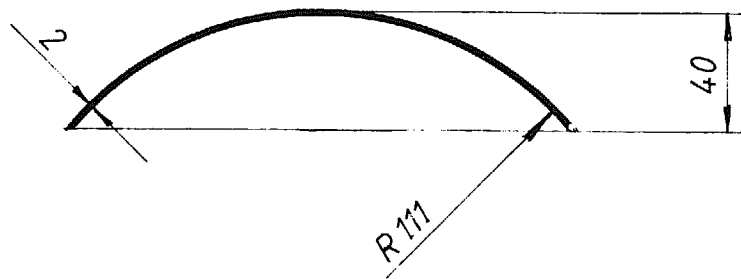
M 1:2,5

1 sheet   2x 192 x 135

RUNNER BLADE   (14 nos. required)

07/03

A 17

M 1:10

17/01 welded
during assembly

08/03

08/01

200
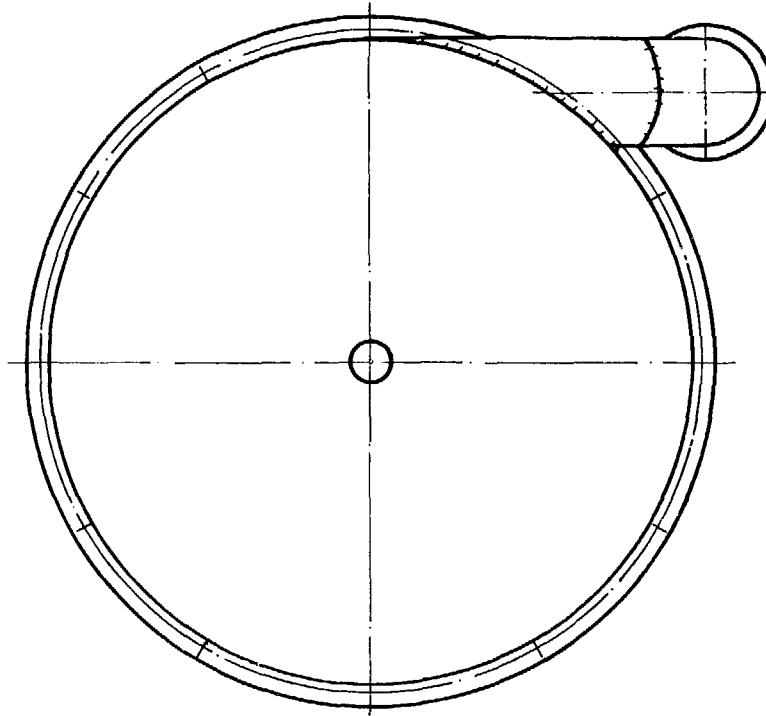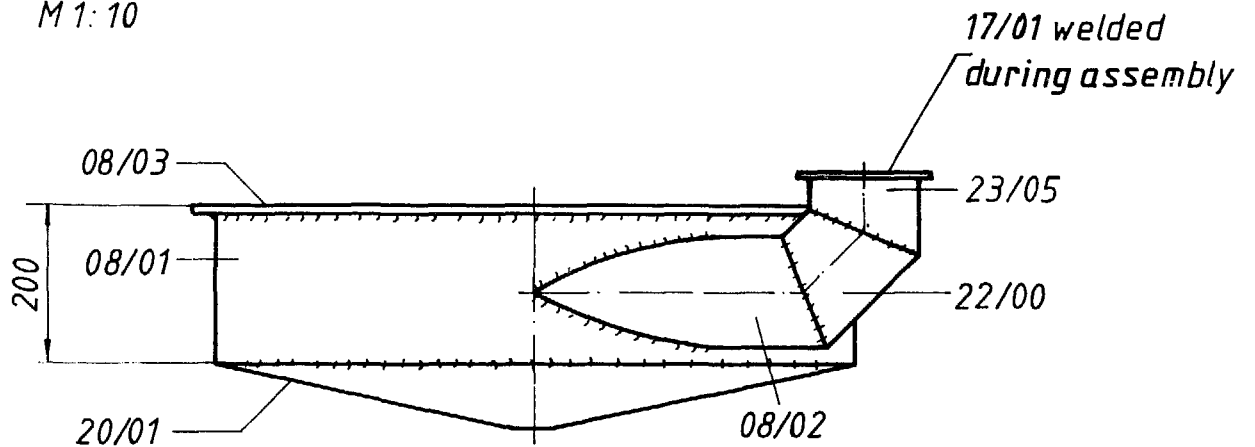
23/05

22/00

20/01

08/02

Note: to avoid distorted flanges, bolt two 08/03 together and
weld 08/01 to one of them.

1	flange	17/01
1	pipe section	23/05
1	pipe section	22/00
1	cone	20/01
1	flange	08/03
1	pipe section	08/02
1	housing ring	08/01

HOUSING ASSEMBLY

08/00
A18

32

80

106

130

152

130

80

cut out

378

340

280

240

200

113

50

15

2700

100

200
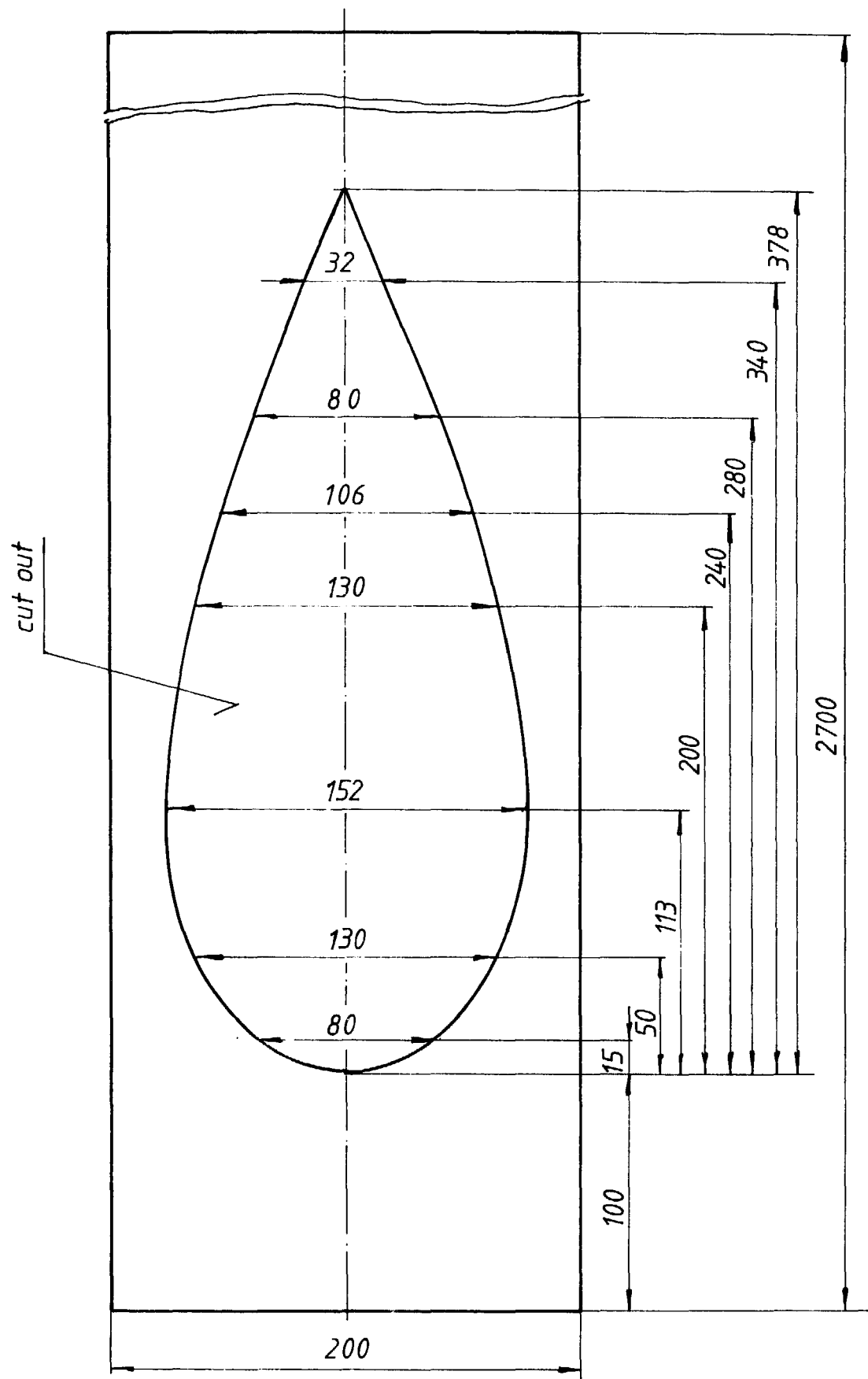
M1: 2,5

1 sheet   2x 200x 2700   Ms

HOUSING RING

08/01

A 19

400

249

182

97

298

324

332

249

12 x 40≈476

40

476

development
inner side

1,5

R 430

Ø 153
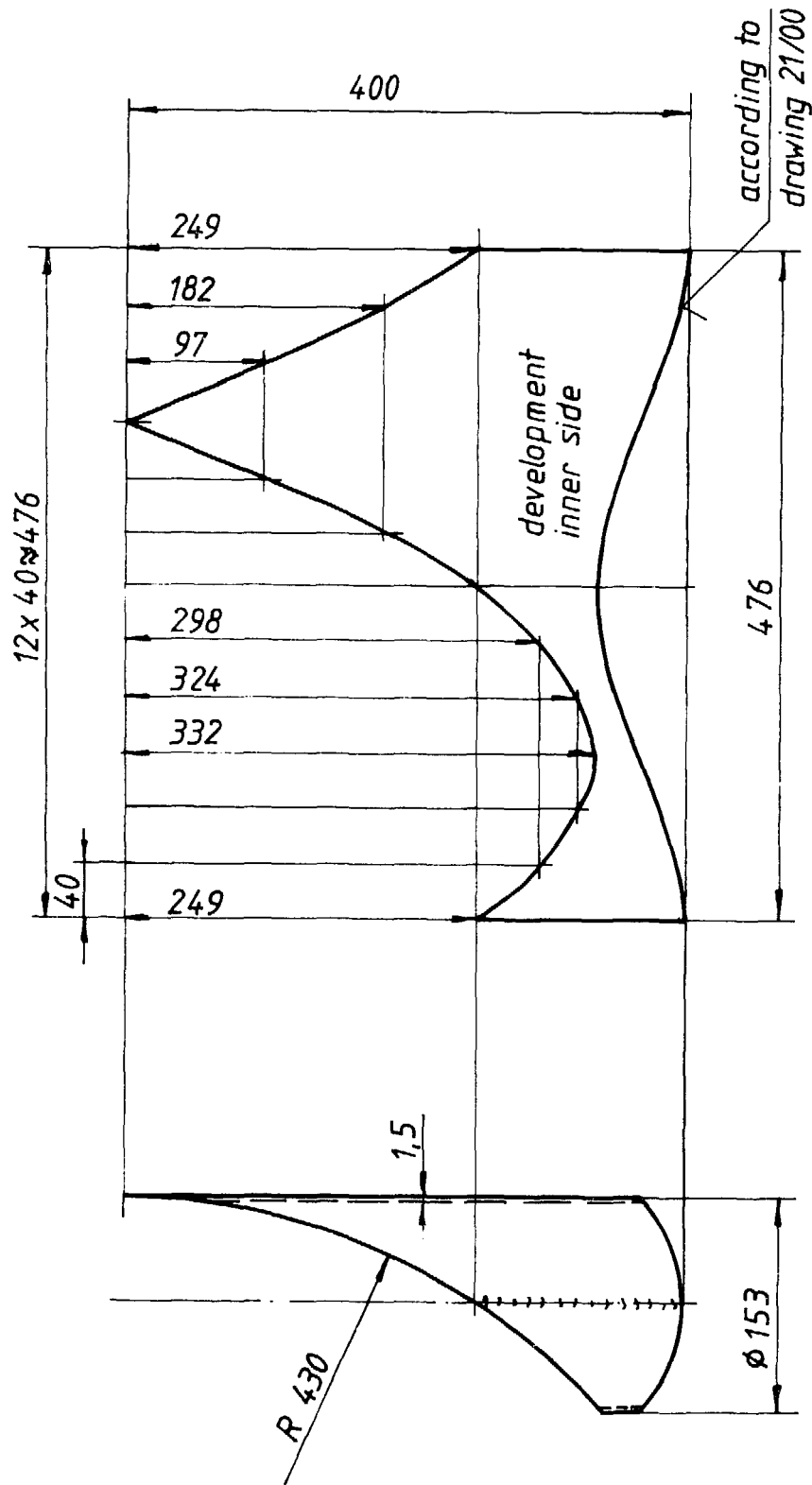
M1:5

1 sheet 1,5 x 400 x 476 Ms

PIPE SECTION

08/02

A 20

6

ø 9

30

ø 900   12 holes x 30°

ø 860

≃
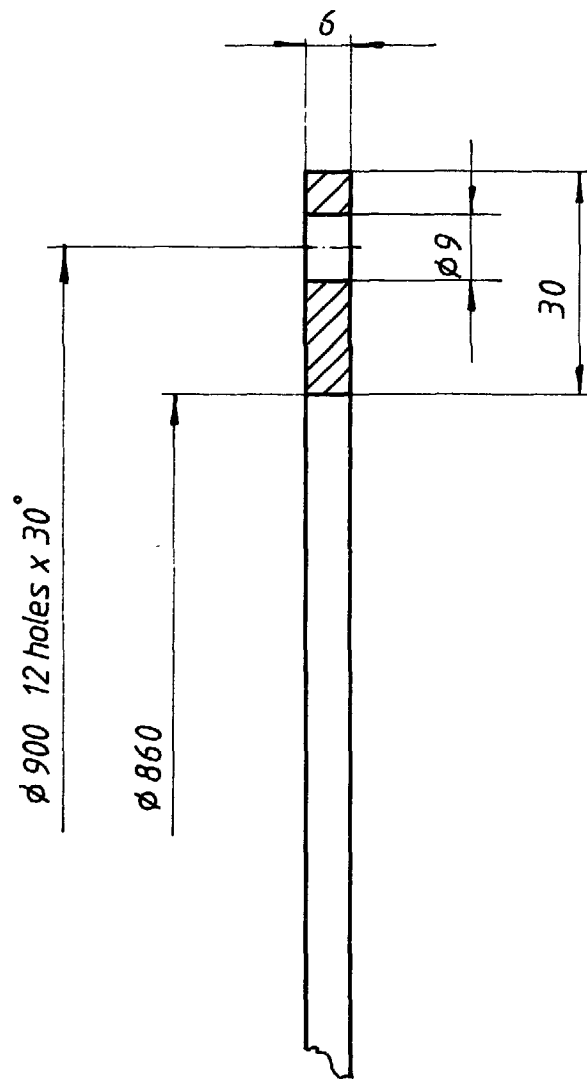
1   flatiron   6 x 30 x 2796   Ms

FLANGE   (2 nos. required)

08/03

A 21

670

- flange 17/01 tapered
  to fit cone 20/05

- bolt 12/00 and flange
  filed to enable removal
  of 17/01

08/03   20/05   11/01   17/01

12/00 welded to 20/05

15

3
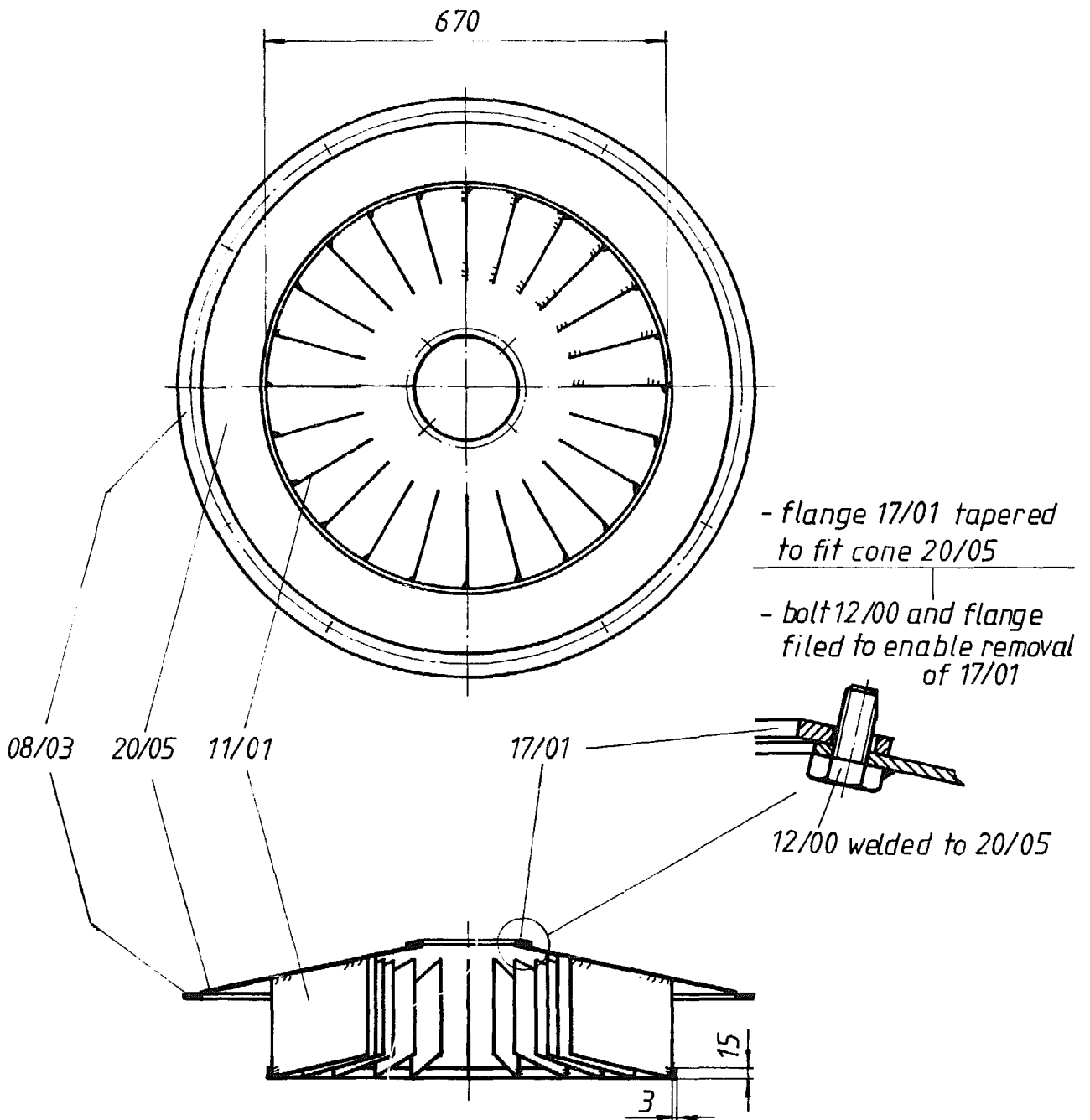
Note: to avoid distorted flanges, bolt 08/03 to housing 08/00
      and weld cone 20/05 to flange

M 1:10

1	flat	15 x 3 x 2114
1	flange	17/01
1	cone	20/05
24	baffle plate	11/01
8	bolt	12/00
1	flange	08/03

COVER ASSEMBLY

11/00

A 22

160

12°

160

12°
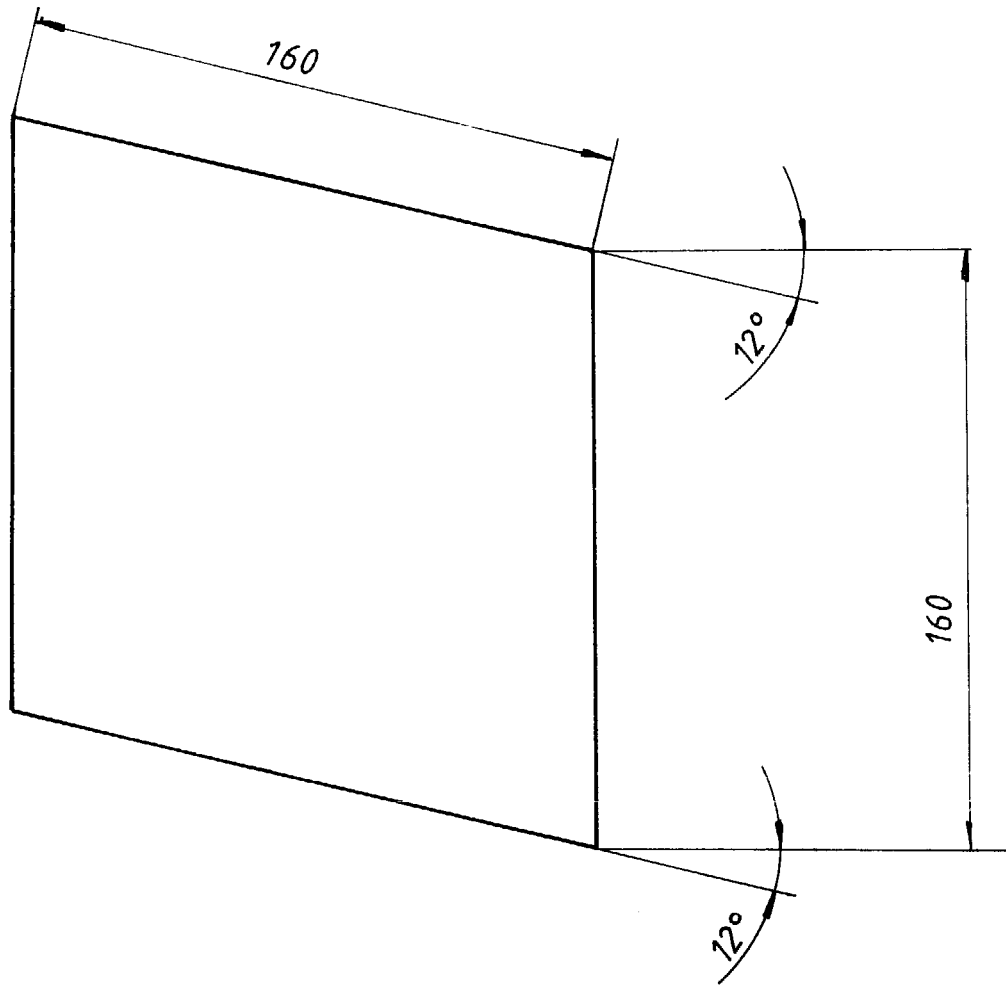
M 1: 2

1 sheet   2 x 160 x 160   Ms

BAFFLEPLATE   (24 nos. required)

17/01 welded during assembly

~25

13/01

22/00

13/02

17/01 welded
during assembly

22/00

23/06

M1: 5
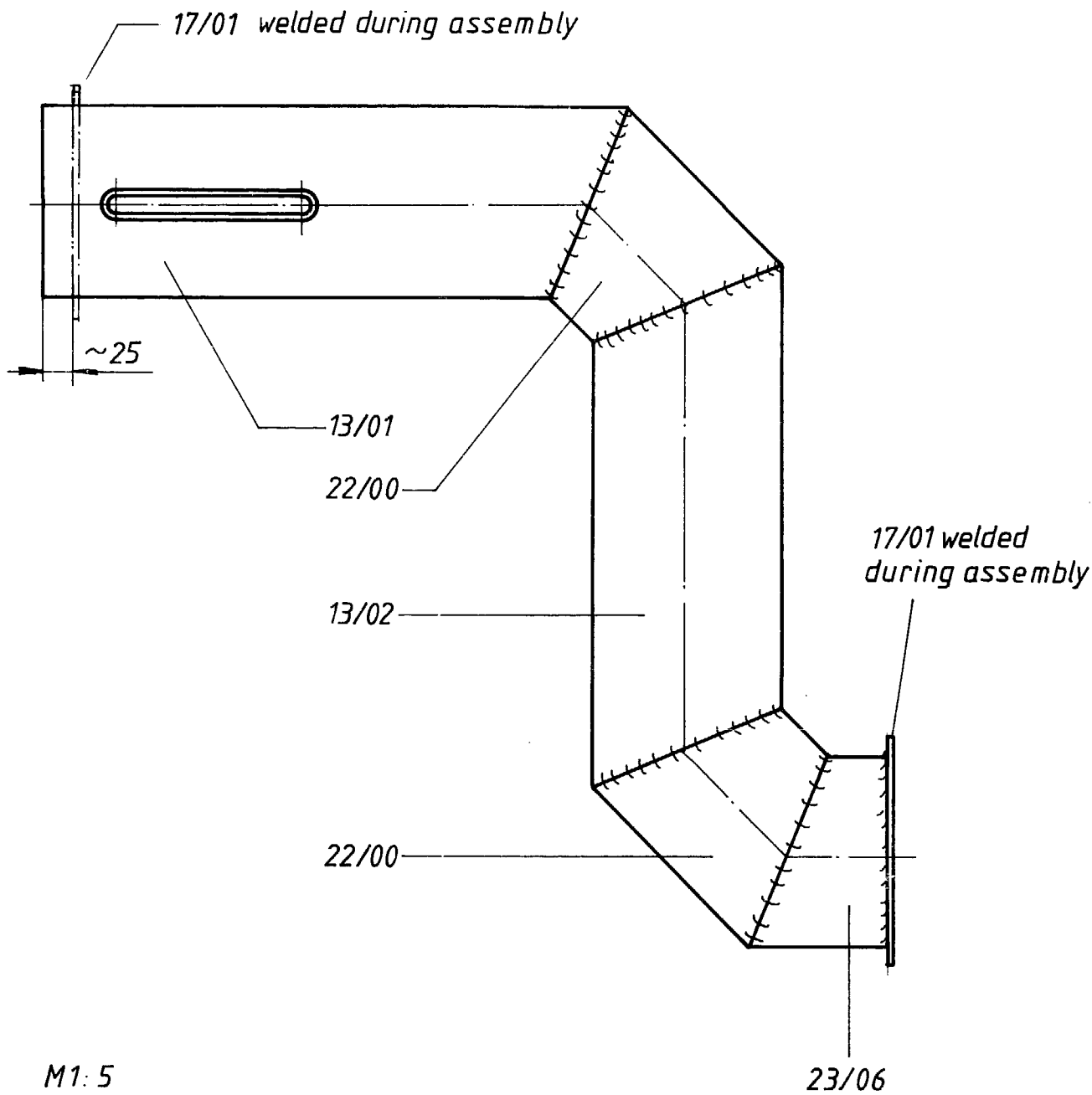
1	pipe section	23/06
2	"	22/00
1	"	13/02
1	valve guide	13/01
1	flange	17/01

INLET PIPE ASSEMBLY

13/00

A 24

470

150   60

22

240   476

14

development

22,5°

1,5

butt weld

Ø153
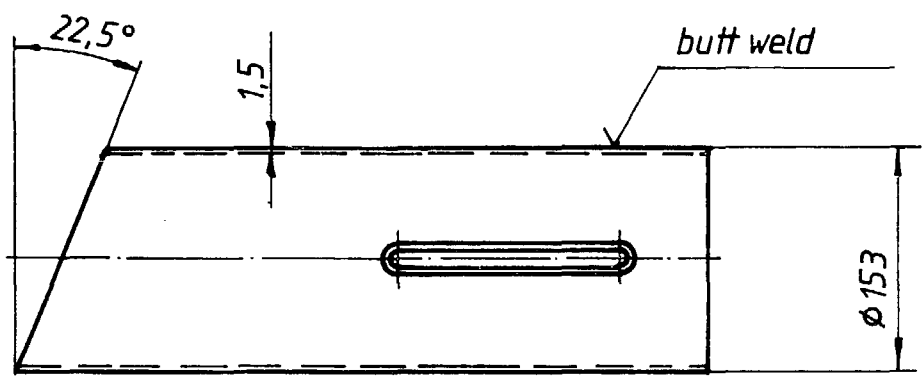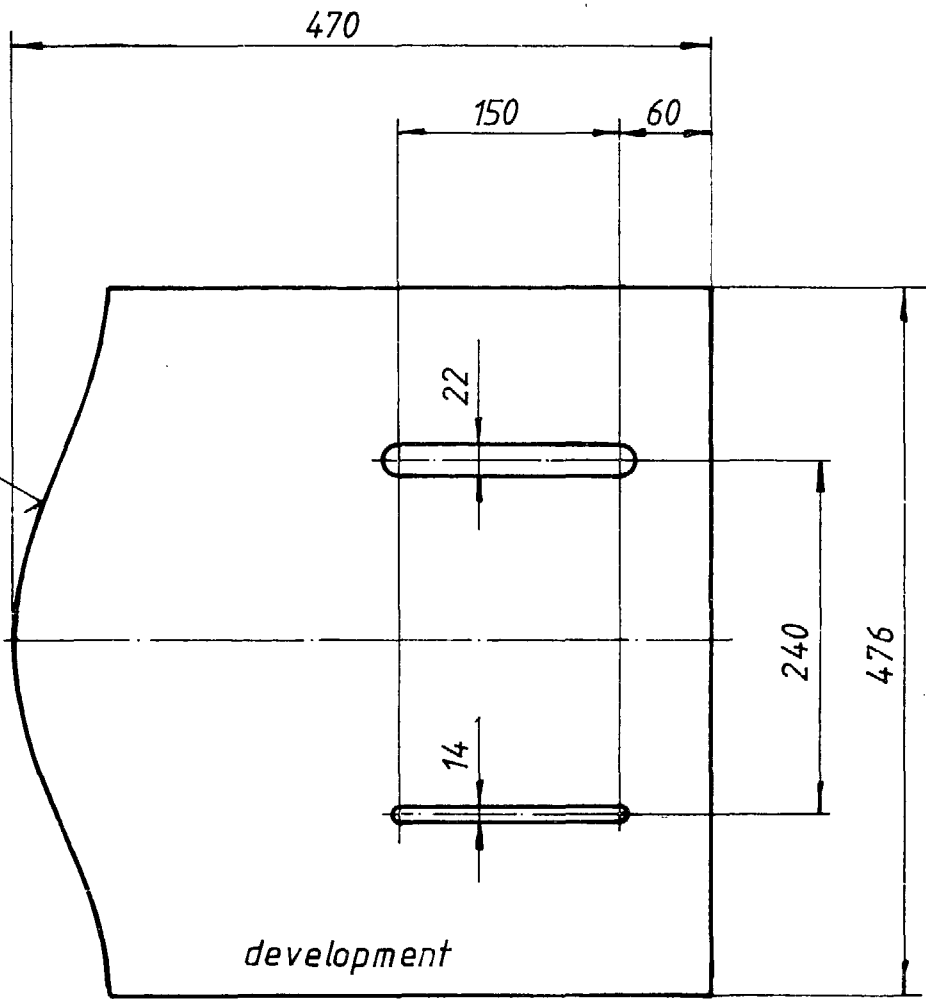
M1:5

1 sheet   1,5x470x476   Ms

VALVEGUIDE

13/01

A 25

416

476

according to
drawing 21/00

1,5

butt weld

Ø 153

315
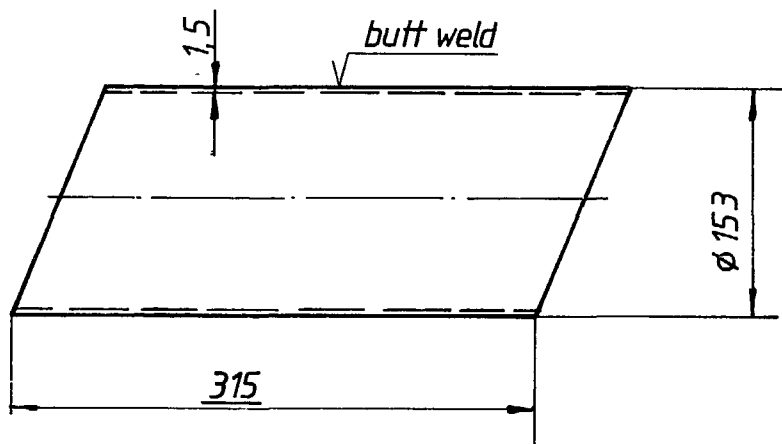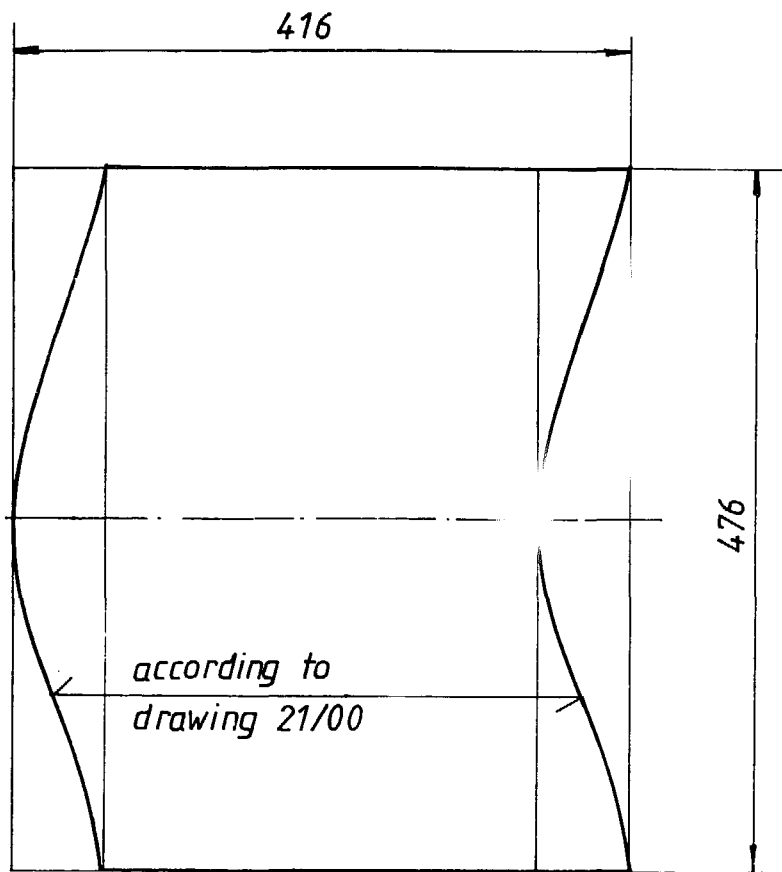
M1:5

1 sheet   1,5 x 476 x 315

PIPE SECTION

13/02

A 26

ø325

20/06

ø14

ø22

410

180

M 1:2,5

ø148
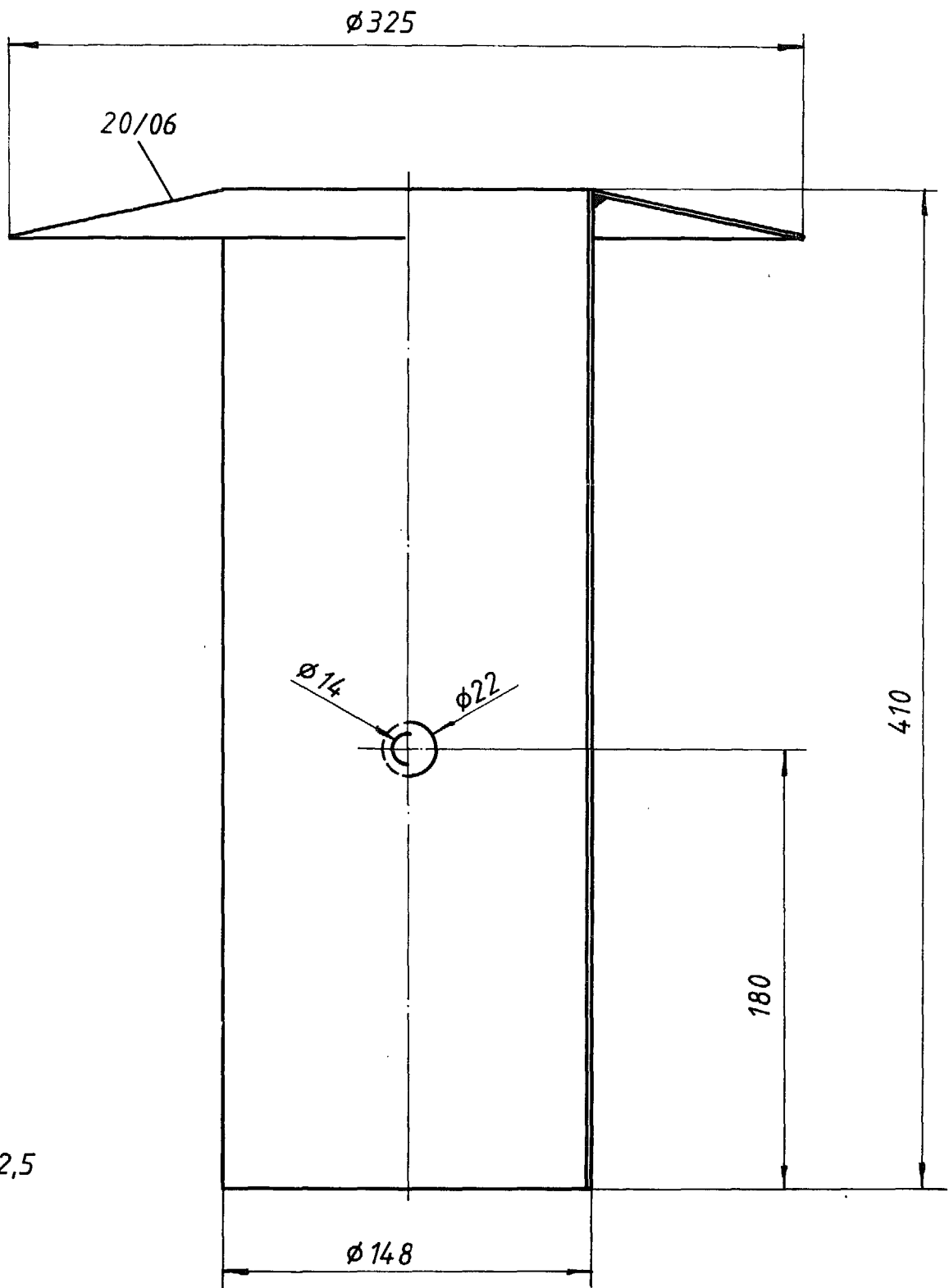
| 1 | cone | 20/06 | |
| 1 | sheet | 2x410x458 | Ms |

VALVE

14/00

A 27

2x45°

Ø30

M12

knurled

100

35

25

20

Ø20

175

275

knurled

2x45°

Ø30
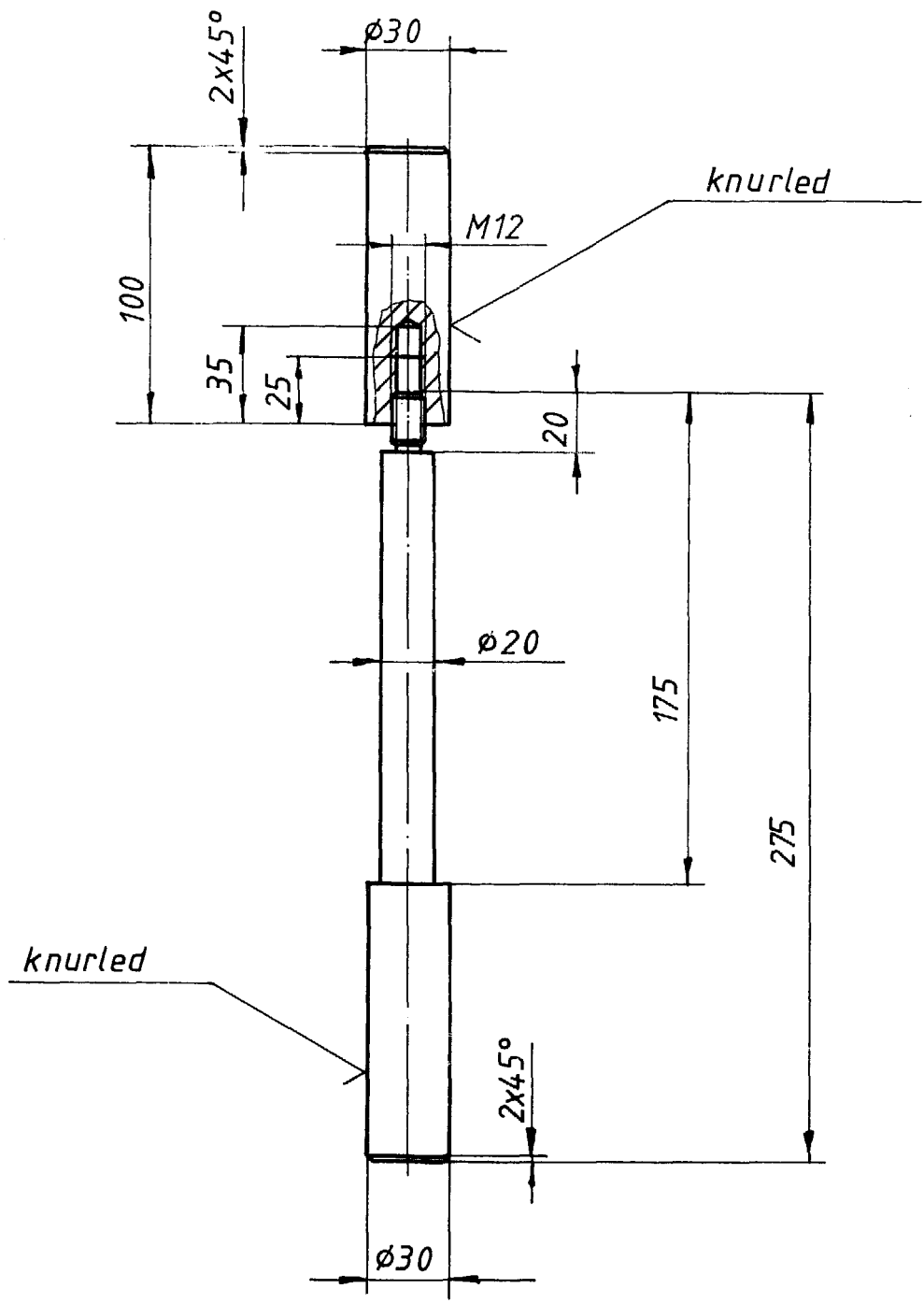
M 1: 2,5

| 1 | rod | Ø30 x 278 Ms |
| 1 | rod | Ø30 x 103 Ms |

HANDLE

15 / 00

A 28
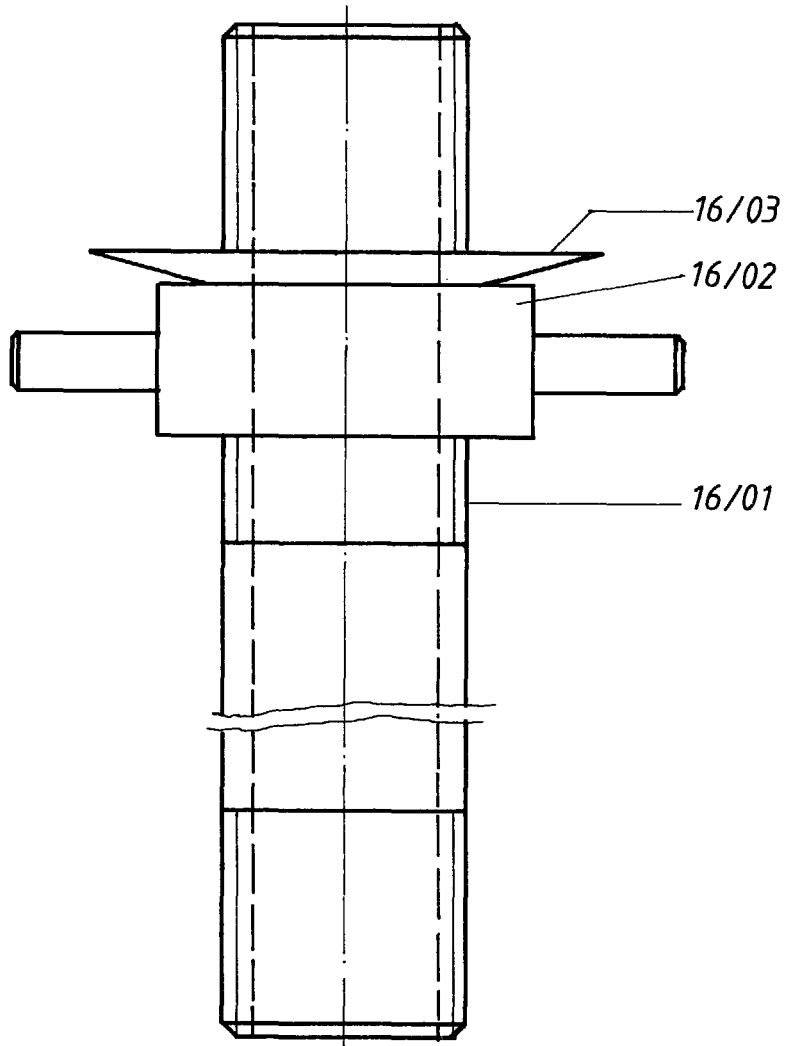
16/03

16/02

16/01

1	cone	16/03
1	nut	16/02
1	pipe	16/01

DISCHARGE PIPE ASSEMBLY

16/00

A 29

R 1"

70

450

30

R 1"
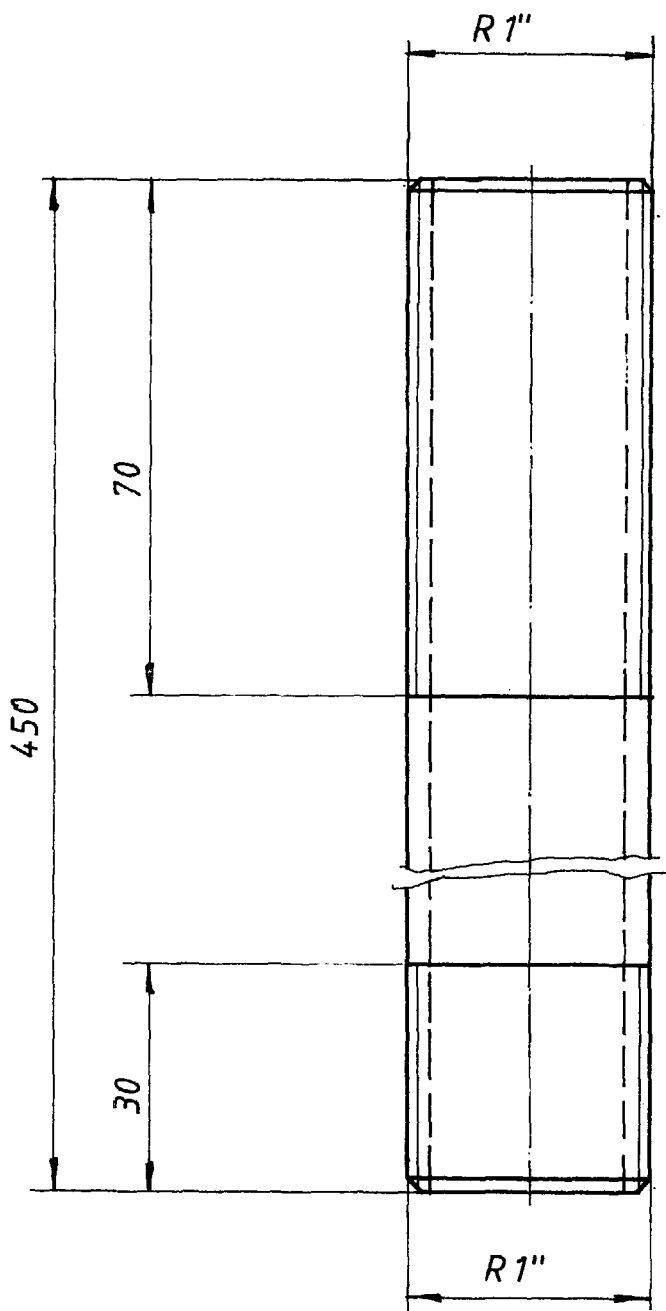
M 1:1

| 1 | GI-pipe | 1"x 450 |

PIPE

16/01

A 30

20

20

∅8

R 1"

50

M 1:1

| 2 | rod | ∅ 8 x 20 |
| 1 | rod | ∅ 50 x 20 |

NUT

16/02

A 31

$\phi 30$

$\phi 70$

5
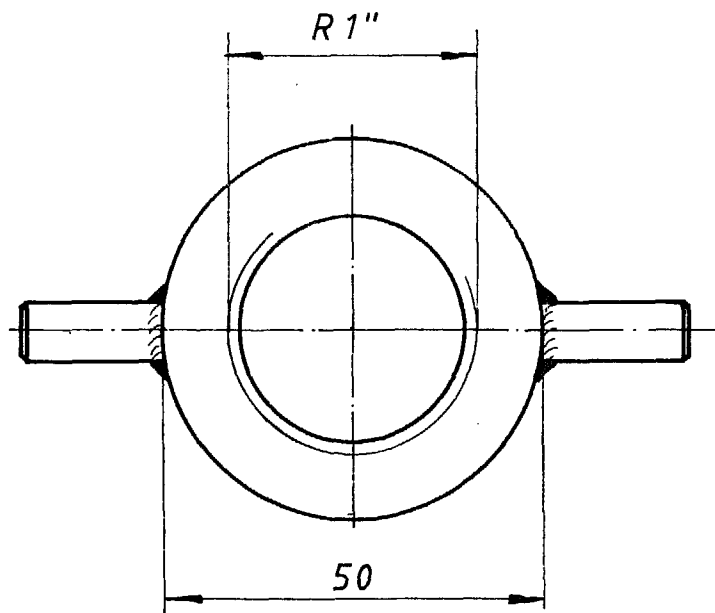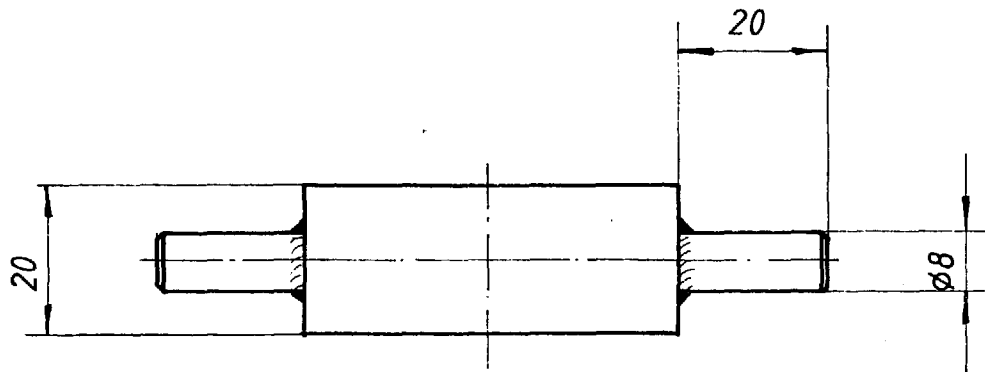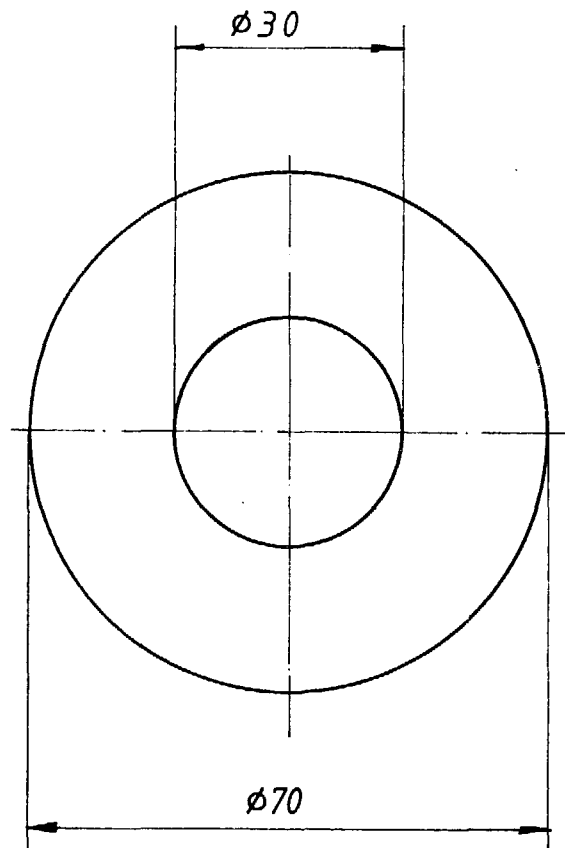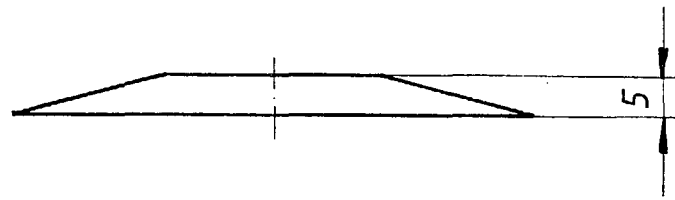
M1:1

1   sheet   1,5 x 80 x 80

CONE

16/03

A 32

6

350

according to
kettle 18/00

100

550

20/07
20/08
23/03
23/04

23/01
23/02

22/00
17/01

22/00
17/01

600
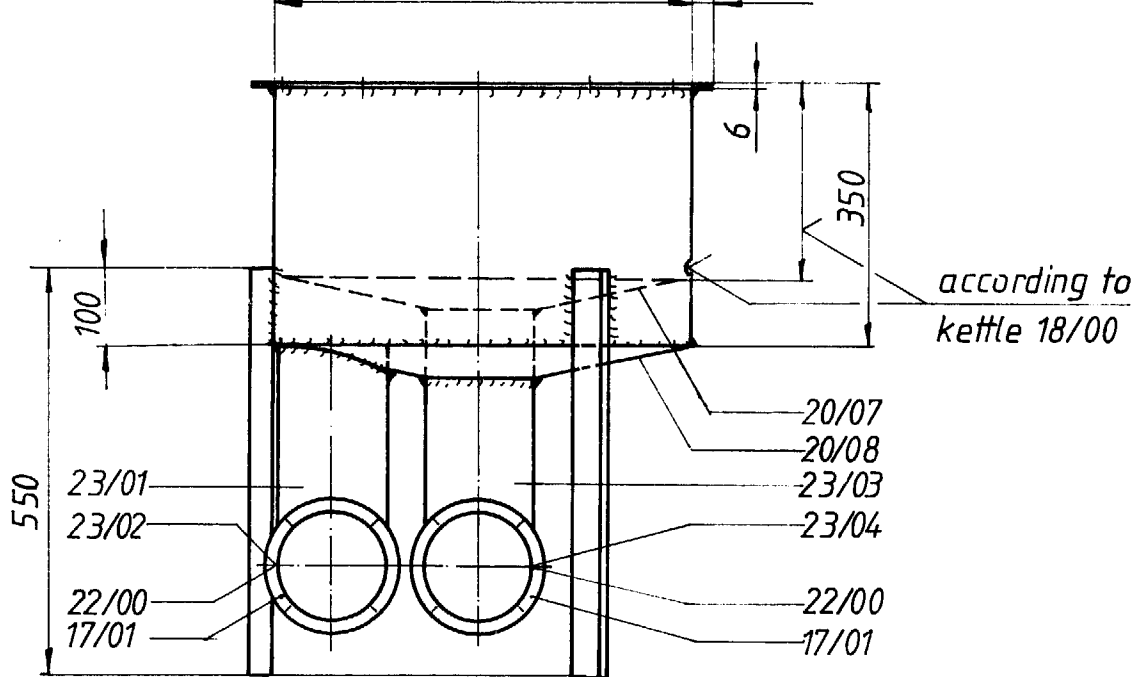
cut hole with Ø155
in cone 20/07 for
pipe section 23/01
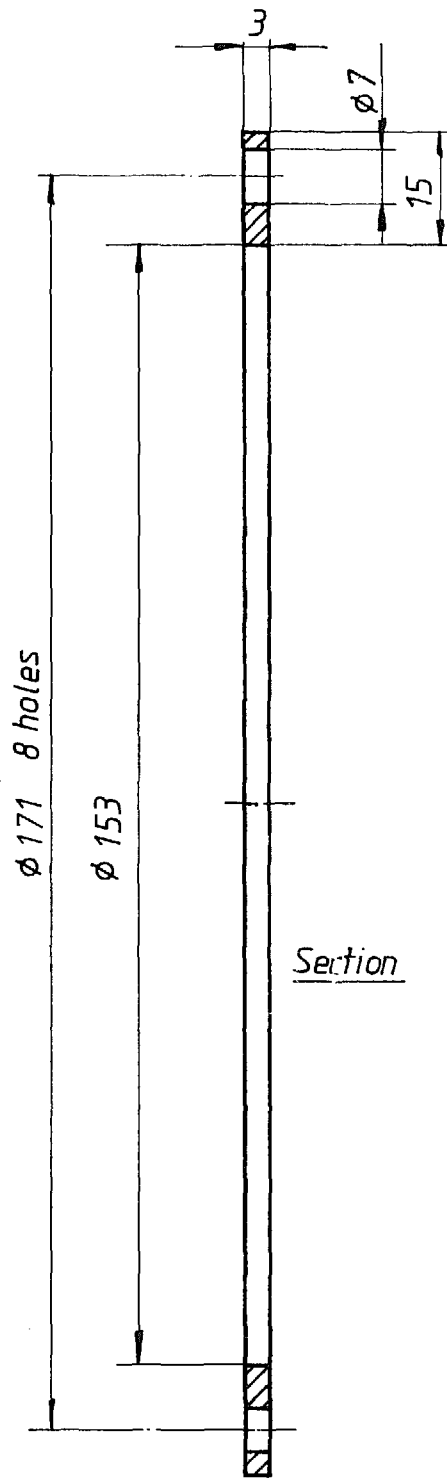
M1:10

200

9
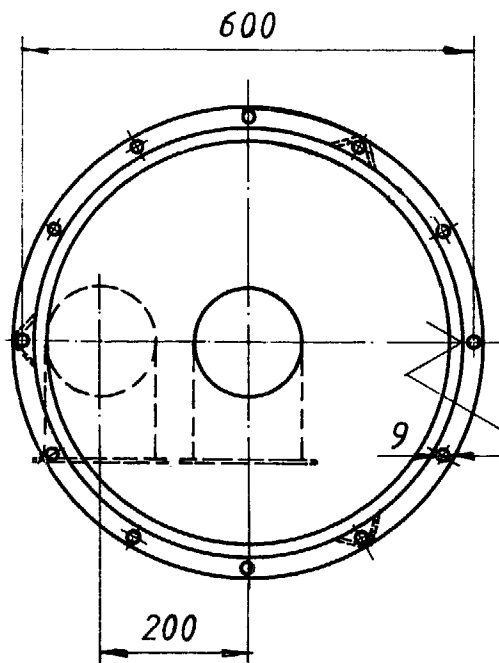
Manufacturing process:

1. bolt flange to flange of
   kettle 18/00 and weld
   jacket.
2. weld pipes, put 20/08
   on 23/03 and weld 20/07
3. put these parts in place
   so that 20/07 rests in
   reset formed by fins
4. weld 20/08 to 23/03
   and jacket.
5. mark hole for discharge
   pipe 16/00, take kettle
   off and cut hole Ø 30.

1	pipe section	23/04	
1	"	23/03	
1	"	23/02	
1	"	23/01	
2	"	22/00	
1	cone	20/08	
1	cone	20/07	
2	flange	17/01	
3	angle	45 x 45 x 550	
1	flat	6 x 30 x 1870	
1	sheet	1,5 x 350 x 1780	

KETTLE HOUSING ASSEMBLY

17/00

A 33

3

ϕ 7

15

ϕ 171   8 holes

ϕ 153

Section

M 1: 1

1 flat   3 x 15 x 530

FLANGE   (7 nos. required)

17/01

A 34

ø625

ø500

3

3

450

250

R 1"

ø50

3

15 | all fins must have
this distance !

weld full length
of fin !

30

A

A

ø600

9

M 1:5
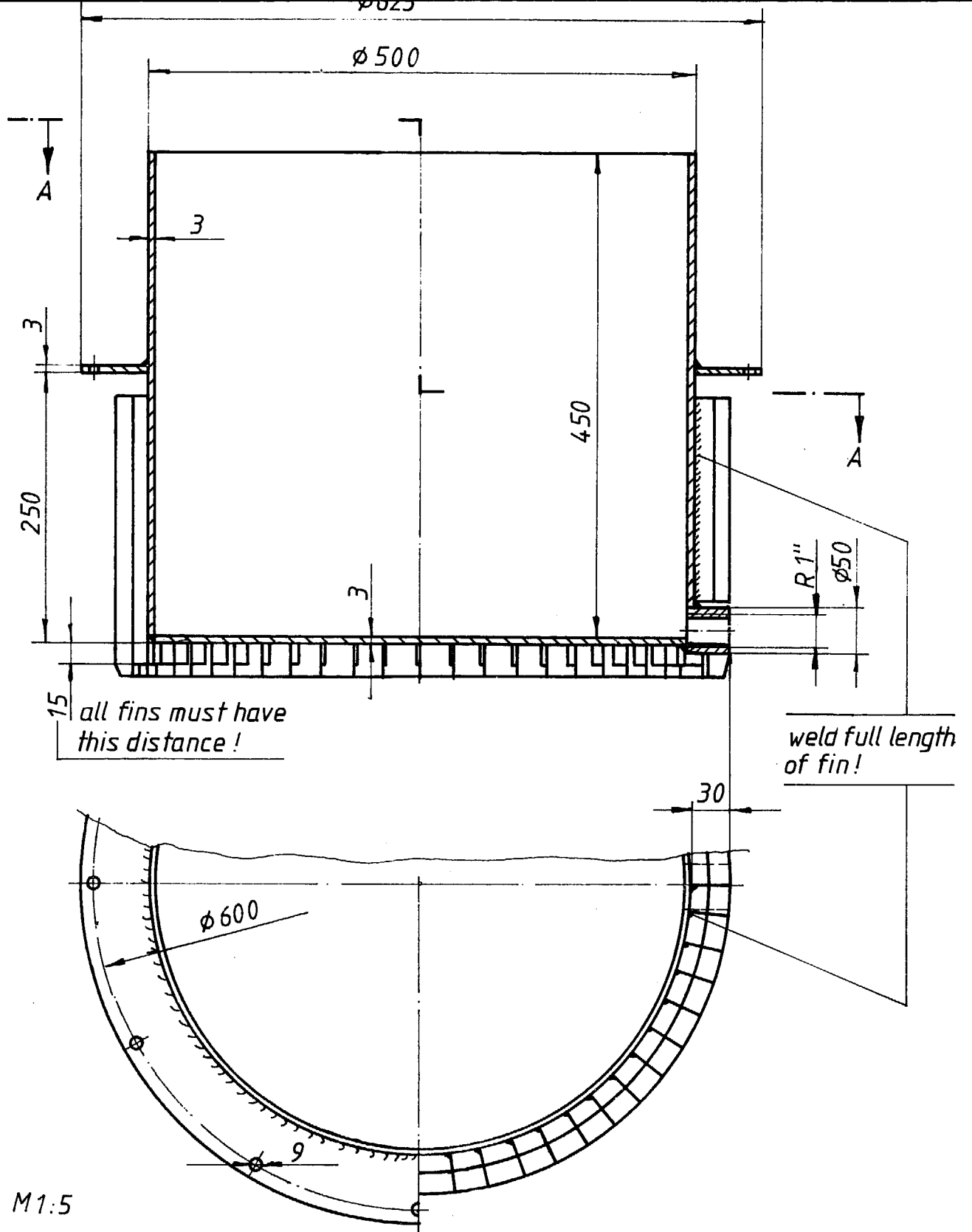
80	fin	18/01	
1	rod	ø50 x 35	
1	sheet	3 x 450 x 1561	
1	sheet	3 x 625 x 625	cut out of this both bottom and flange

KETTLE ASSEMBLY

18/00

A 35

5

10

15

255

22

2

30

14

14

48

development
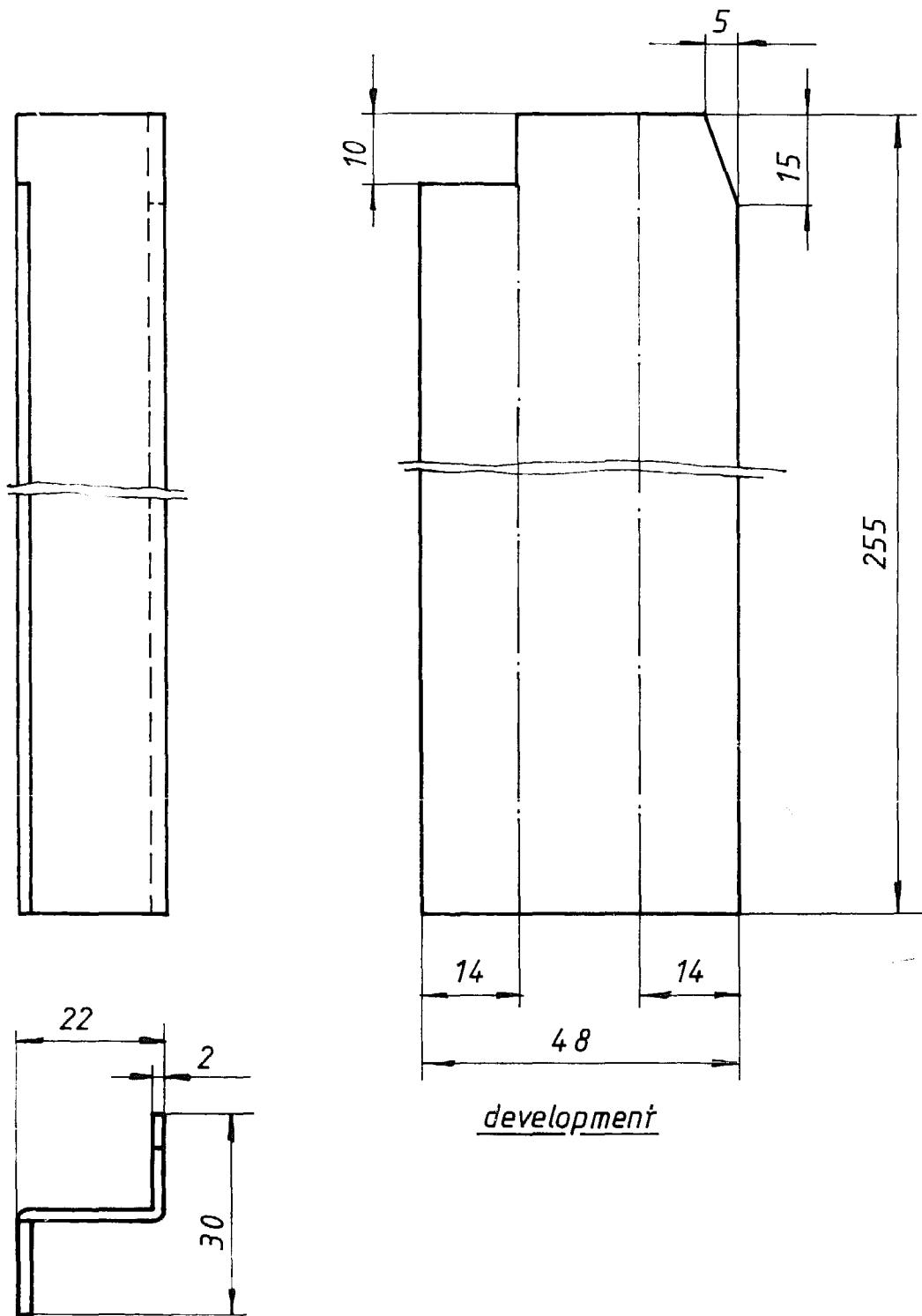
M1: 1

1 sheet   2x48x 255 Ms

FIN   (80 nos required)

18/01

A 36

17/01

butt weld
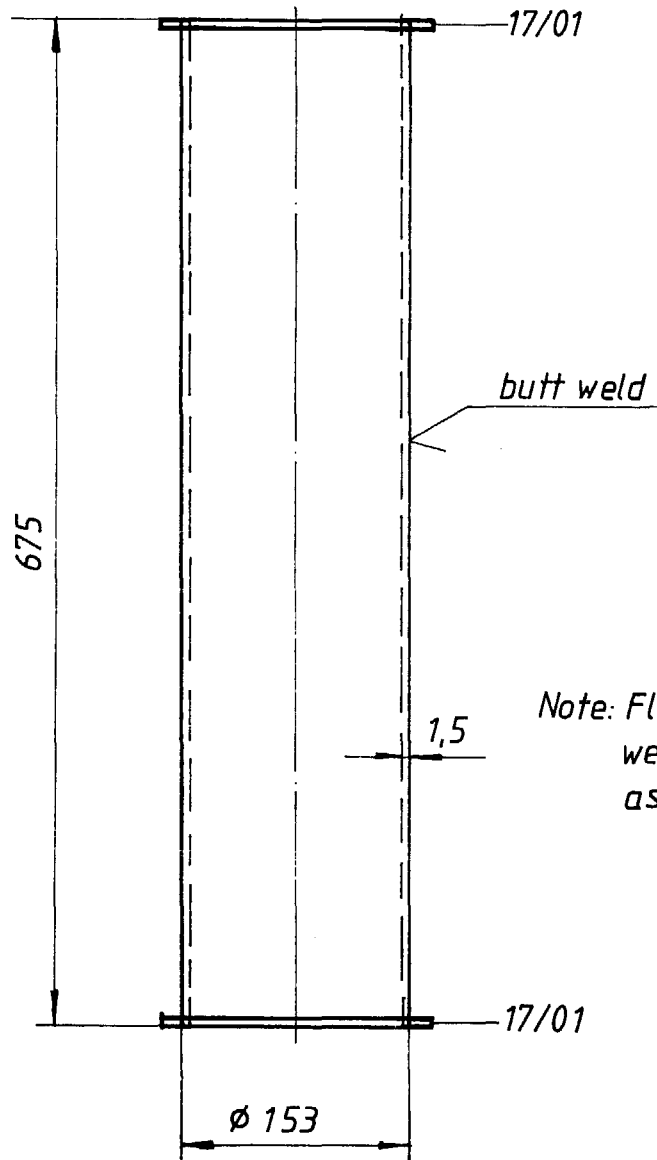
675

Note: Flanges 17/01
welded during
assembly

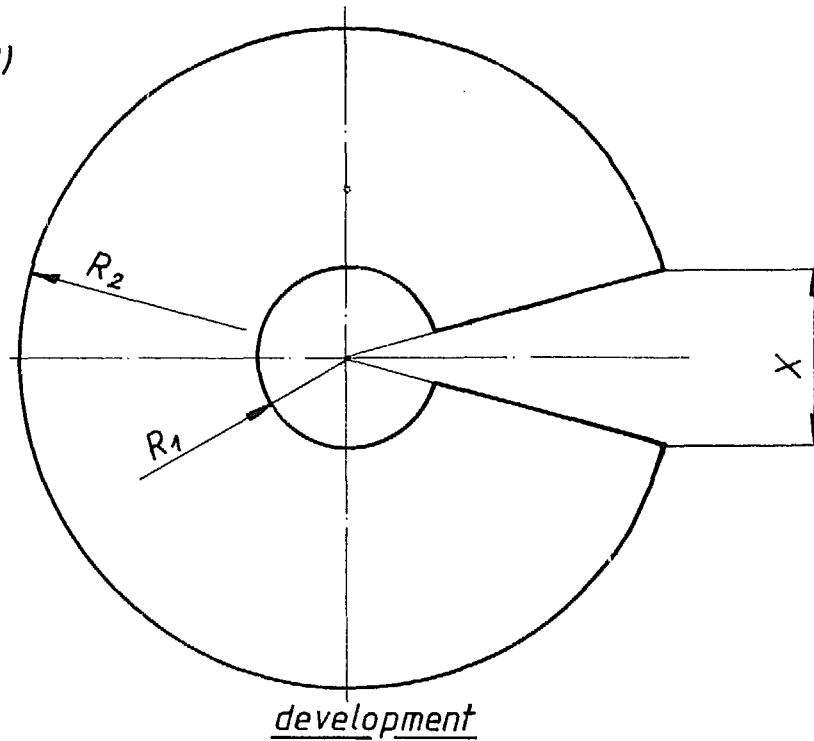1,5

17/01

Ø 153

M 1:5

PIPE SECTION

19/00

A 37

section
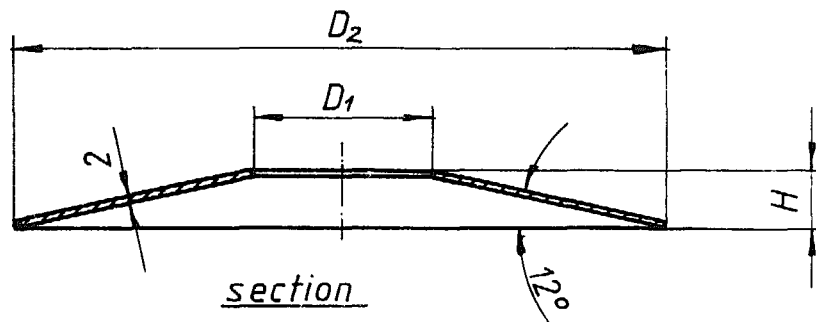
formulas:

$$R = \dfrac{D}{2\cos 12°} = 0,511\,D$$

$$X = 2R_2 \sin\dfrac{(2R_2 - D_2)\,90}{R_2} = 0,07\,D_2$$

$$H = 2 + (\dfrac{D_2 - D_1}{2}\,\tan 12°)$$

development

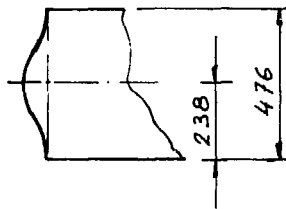| cone no.	D_1	D_2	H	X	R_1	R_2	req.no.	used in	
20/08	150	570	47	40	77	291	1	kettle housing	17/00
20/07	150	530	42	37	77	271	1	kettle housing	17/00
20/06	150	325	21	23	77	166	1	valve	14/00
20/05	160	860	76	60	82	440	1	cover	11/00
20/04	120	325	24	23	61	166	1	runner	7/00
20/03	330	670	38	47	169	343	1	runner	7/00
20/02	120	670	61	47	61	343	1	runner	7/00
20/01	50	860	88	60	26	440	1	housing	8/00

CONES

20/00
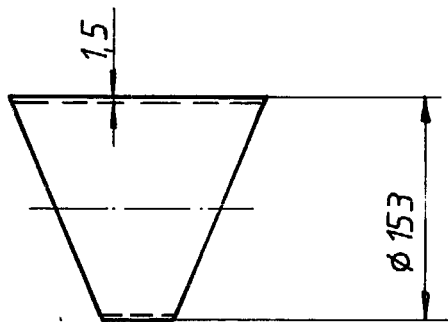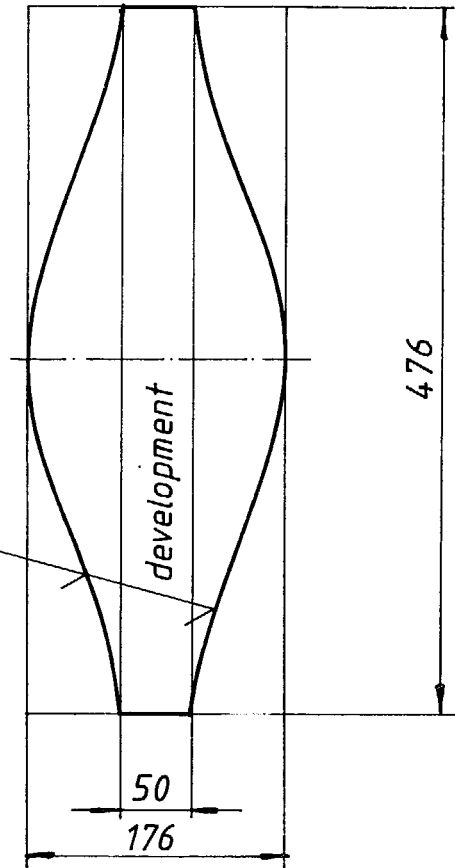
A 38

M 1:1

63

238
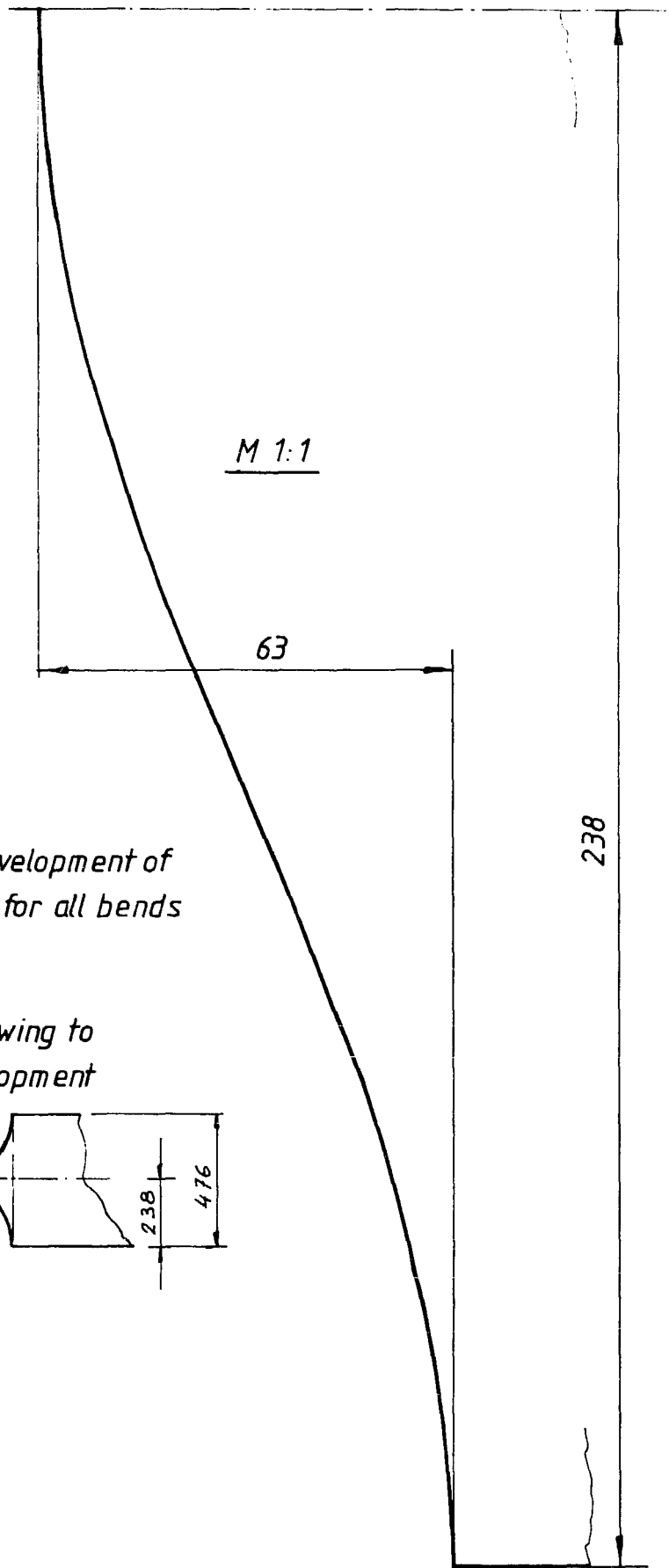
Note: This is half   the development of
      a 45° bend, ⌀ 150, used for all bends
      of the piping system

      For marking use this drawing to
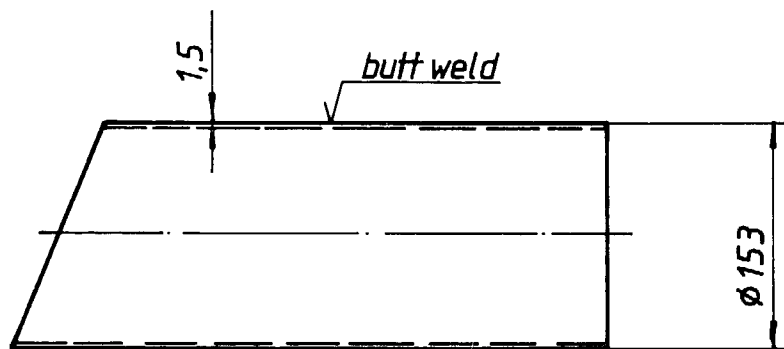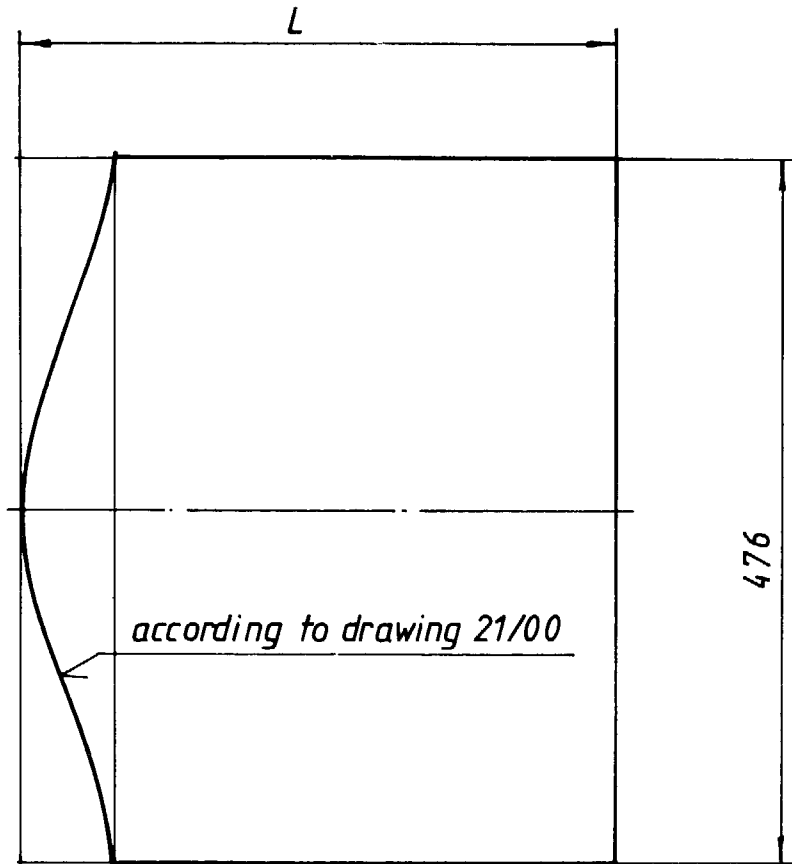   to obtain the full development
      looking like this:

238   476

DEVELOPMENT (BENDS)

21/00

A 39

according to drawing 21/00

development

476

50

176

1,5

Ø 153

M 1:5

1 sheet   1,5 x 176 x 476   Ms

PIPE SECTION (5 nos. required)

22/00

A 40

L

476

according to drawing 21/00

1,5

butt weld

Ø 153

M 1:5

1 sheet	1,5x 476 x	L= 112	used in	13/00	no. 23/06
" "	" "	100	" "	08/00	" 23/05
" "	" "	112	" "	17/00	" 23/04
" "	" "	300	" "	17/00	" 23/03
" "	" "	112	" "	"	" 23/02
" "	" "	245	" "	"	" 23/01

PIPE SECTION

23/00

A 41

SKAT PUBLICATIONS

ENGLISH PUBLICATIONS:

- Manual for Rural Water Supply, by Helvetas, 3rd unrevised edition, 1983, 175 pp., SFr. 34.00

- Elements of Solar Architecture, by Roland Stulz, 2nd unrevised edition, 1983, 22 pp., SFr. 6.50

- Local Experience with Micro-Hydro Technology, by Ueli Meier, 2nd unrevised edition, 1983, 169 pp., SFr. 32.00

- The Segner Turbine - A Low-Cost Solution for Harnessing Water Power on a Very Small Scale, by Ueli Meier et al., 1983, 16 pp., SFr. 4.00

- Appropriate Building Materials - A Catalogue of Potential Solutions, by Roland Stulz, 2nd edition, 1983, co-publication with Intermediate Technology Publications, London, 332 pp., SFr. 24.00

- New and Renewable Energies, by Ueli Meier and Urs Rentsch, 1st edition, 1983, co-publication with ENDA, Dakar/Senegal, 73 pp., SFr. 10.00

- Survey, Design and Construction of Trail Bridges for Remote Areas, by Helvetas, 5 volumes, 1st edition 1983/1984, 950 pp. and 200 design drawings, SFr. 356.00

FRENCH PUBLICATIONS:

- Manuel Technique pour l'Approvisionnement en Eau des Zones Rurales, by Helvetas, 2nd unrevised edition, 1983, 175 pp., SFr. 39.00

- Energies Nouvelles et Renouvelables, by Ueli Meier and Urs Rentsch, 1st edition, 1983, co-publication with ENDA, Dakar/Senegal, 73 pp., SFr. 10.00

- Le Compendium des Fourneaux à Bois, by the Woodstove Group of the University of Eindhoven, 1st French edition, 1984, co-publication with Association Bois de Feu/Marseille, Edisud/Marseille and ENDA/Dakar, approx. 379 pp., approx. SFr. 30.00

SPANISH PUBLICATIONS:

- Desecador Solar Simple, by SKAT, 1st edition, 1980, 26 pp., SFr. 7.50

- Manual Técnico de Aprovisionamiento Rural de Agua, by Helvetas, 1st edition in Spanish, 1984, co-publication with SEMTA, La Paz/Bolivia, approx. 80 pp., approx. SFr. 30.00

- Experiencias Locales con Micro Hidro Tecnología, by Ueli Meier, 1st Spanish edition, 1984, co-publication with CETAL, Valparaiso/Chile, approx. 160 pp., approx. SFr. 30.00

- Alternativas al Transporte en América Latina: La Bicicleta, by Ricardo A. Navarro, 1st edition, 1984, co-publication with CESTA, El Salvador, approx. 200 pp., in preparation

GERMAN PUBLICATIONS:

- Angepasste Technik und die Dritte Welt - Ein Arbeitsbericht der SKAT, by J.-M. Baumer et al., 1st edition, 1983, 143 pp., SFr. 8.00