FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

TECHNICAL MEMORANDUM NO. 52 OF 1965.

PROPOSALS FOR A RESEARCH PROGRAMME INTO THE PRODUCTION OF SMOKELESS SOLID HOUSEHOLD FUEL, CHAR FOR ELECTRO-METALLURGICAL USE AND FORMED COKE FOR BLAST FURNACE USE.

By:

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INTRODUCTION:

During 1958, the Fuel Research Board, after a review of the whole position of fuel research, resolved that instead of dissipating the Institute's limited resources in an effort to cover too wide a range of subjects within the terms of reference of the Institute, given in the Fuel Research and Coal Act, the attention should rather be concentrated on a few subjects with the object of obtaining useful results within a reasonable period of time.

After further study it was also resolved that the subjects of most immediate importance were: the physical and chemical survey of the country's coal resources, coal beneficiation and carbonisation (with the emphasis on the production of metallurgical coke).

The physical and chemical survey of the country's fuel resources is, and will, of course, continue to be a matter of prime importance, especially if a broad meaning is attached to the terms "physical and chemical properties of coal", i.e. that such a survey should cover as many as possible of those factors that affect the usefulness of the fuel in practice. It can, therefore, be visualised that this subject will continue to be an important assignment of the Institute.

Coal beneficiation was tackled on a fairly broad basis, but the energy was soon concentrated on coal washing. Valuable laboratory work was done but it soon

became .../

became apparent that larger scale work was essential.

After giving much thought to the matter, the Fuel Research Board approached the coal industry and Iscor with a pilot plant scheme. It was agreed to establish a special pilot plant advisory committee to work out details, and the coal industry and Iscor finally agreed to make some R500,000 available for the erection of the plant. Through the co-operation of a number of appliance makers who either donated equipment outright or made it available at much reduced prices a pilot plant could be erected that was valued at R750,000 on completion. In the course of time the plant was expanded to make it more useful.

The carbonisation research was also started in a small way. Although the need for larger scale research was also felt it was not necessary to erect quite such an elaborate pilot plant, as Iscor was prepared to co-operate so that full-scale oven tests could be done on many occasions. The required pilot plant equipment was provided with the assistance of Iscor and a coke oven plant manufacturer.

The policy adopted by the Board has been amply justified since valuable information has been obtained in these fields in a matter of a few years.

The coal preparation pilot plant was initially used almost exclusively for research on washing processes and to determine certain characteristics of South African coals. More and more use of the facilities has, however, been made by the industry to obtain data on their coal, information on processes or to have coal specially prepared for other studies. In fact, during the last 3 years the plant was often so fully occupied with such studies that the Institute's own research work had to be temporarily stopped.

In the carbonisation field, general laboratory and pilot plant work is still in progress. Smaller projects have been assigned to the Institute at various times but a major co-operative study with Iscor occupied this division from 1960 to 1964. The object was to determine the potential value of swelling coal reserves for the manufacture of metallurgical coke. In this study the availability of the coal preparation pilot plant was of special value. When this investigation was at its height up to 10,000 tons per annum of coal were specially prepared for carbonisation experiments.

It may be concluded that the sponsors who helped so substantially to provide the pilot plant facilities have already reaped much benefit from them and will continue to do so for many years to come. Due to the experience gained by the staff many of the problems brought to the Institute can be dealt with much more expeditiously than in the past and this is also to the benefit of the industry.

However, during 1964, when some of the major studies, such as the co-operative Iscor-F.R.I.-project came to a close, the Fuel Research Board considered the time opportune to review the fuel research position again to determine whether attention should now be focussed on other problems, or whether the field of activities should be expanded.

This does, of course, not imply that existing laboratory or pilot plant facilities would become redundant. As indicated above they are now becoming more generally used and they would also constitute a very valuable asset in some of the investigations that have been envisaged.

This report deals, mainly, with one avenue that was explored during the last two years, after giving attention to the general trends in the fuel and energy market and the requirements of the iron and steel and other industries in the Republic.

The position is summarised in the next section.

FUEL .../

FUEL TRENDS IN SOUTH AFRICA.

(a) The Energy Position:

The rapid industrial development of the Republic during the past decades was in no small measure due to the availability of cheap coal.

However, as elsewhere in the world, the trend is towards refined forms of energy or "luxury" fuels as the general standard of living improves, and this trend is accelerated by the growing awareness of atmospheric pollution.

Potentially, there is, probably, a large outlet for a suitable solid fuel as domestic energy source for the bantu population, as the traditional fuels such as wood and dung are becoming scarce even in the bantu homeland areas.

Bituminous coal is presently the cheapest alternative fuel, but it can obviously not be used by the bantu in the way traditional to wood-fuel.

Considering exports, it would appear that there may be more hope of selling anthracite or manufactured solid smokeless fuel, char for electro-metallurgical purposes and, possibly, "form-coke" than bituminous coal, provided these commodities can be offered at attractive prices.

In the inland market bituminous coal still has a price advantage over furnace oil, but the margin is becoming small in the coastal industrial areas, where coal bears a heavy burden of railage cost. If coal is, however, to hold its own, much more attention will have to be paid to efficiency in use, either by better operation or by the use of more suitable equipment.

It therefore appears that the solid fuels industry must take cognisance of trends and must accept that more will have to be done in future to retain and expand fuel markets than appeared to be necessary in the past.

Here .../

Here the industry is faced by the fact that the economic conditions in any country dictate that the added cost of special processing cannot exceed a certain limit. South Africa with its traditionally low pit head price for coal is particularly vulnerable in this respect. Its economic ceiling of added cost is lower than that, e.g., in the United Kingdom where a processing cost of say R2 per ton has a much smaller effect on the final price of the solid fuel (due to the relatively high pit head price of coal) than in South Africa where the present pit head price ranges from R1.30 to R1.70, depending on the coal-field.

Although, therefore, various transformation processes are offered in overseas countries, many of which are not regarded as economic under the conditions prevailing in those countries, it is patently clear that it is necessary to study the problem in this country in an effort to arrive at a solution that will be acceptable under South African economic conditions.

Even in the appliance field a locally acceptable solution will have to be found in many instances, especially in the domestic appliances field, since conditions in South Africa differ appreciably from those in most of the developed countries.

(b) <u>Coal as a Source of Metallurgical Coke or other Reductant for Electro-Metallurgical use</u>.

During the last decade, there has been a considerable expansion in the iron and steel industry but the growth in demand has been even greater.

Iscor's expansion programme is now several years ahead of schedule and the 4.5 million ingot tons per annum target, orginally set for 1973 will now be achieved by 1969. In a recent address Iscor's Chairman has already mentioned the possibility that a third, fully integrated steelworks may be established in the Republic.

Amcor has increased its pig iron production substantially so as to satisfy the growing inland demand as well as large overseas contracts. In order to meet its

commitments .../

commitments it has established its own coke oven plant.

The electro-metallurgical industry is expanding rapidly. In addition to the much enhanced ferroalloy production by various companies, the Highveld Development Company is basing a steel and vanadium project on the electro-metallurgical processing of vanadium containing iron ore.

South Africa's reserves of iron and chromium ores are so large that the view has been expressed that steel and other ferroalloys may in time to come be called upon to replace gold as the country's industrial backbone.

Now, the research of the past years has proved that there are sufficient reserves of coking and weakly coking coal to provide for the present volume of metallurgical coke production, during, say, the next 20 - 25 years.

However, the coke presently made from available coking coals is usable but falls short in certain respects (e.g. ash content and strength) to enable the steel industry to derive the full economic advantage of the latest advances in blast furnace technology. Furthermore, the production of prepared coking coal from some virgin areas presents appreciable mining, technical and economic problems.

Under these circumstances serious consideration must be given to the provision of acceptable, and if possible, higher quality coke or coke substitutes to ensure that the steady expansion of iron and steel production, which is a vital necessity for the country's healthy development, will be assured.

The electro-metallurgical industry started by using metallurgical coke as reductant, but it is now more interested in the use of chars that have certain desirable properties.

The reductant need not have great strength and therefore the char can be made from non-coking coal provided that the coal satisfies the specification regarding, e.g. the phosphorus, alumina and silica contents.

Although ..../

Although char is already being made in the Republic, experience has shown that its usefulness also depends on the processing conditions, but a systematic study of the effect of these conditions still has to be done.

(c) Summary and Conclusions Derived from the Survey:

One conclusion drawn from the survey was that attention must be given to the more efficient use of coal as fuel, which implies i.al. education on the one hand and the development of more suitable appliances on the other hand. This conclusion is merely mentioned in this report. It will be dealt with in greater detail elsewhere.

The other conclusion was that additional processing, beyond crushing, size grading and washing of coal would be needed to provide a more acceptable fuel for certain applications on the one hand and a suitable source of carbon for metallurgical purposes on the other hand. It is fairly obvious that some form of heat treatment (with or without controlled oxidation) would be a necessary process step in the production of the desired fuels or coke substitutes, at least from bituminous coal.

A further conclusion was, that the starting material would have to be non-coking coal, accepting that the reserves of coking coal would have to be earmarked for metallurgical coke production by conventional processes. (This would, of course, not necessarily exclude low ash coal showing weakly developed coking properties and prepared e.g. from Witbank duff coals by washing at relatively low specific gravities.)

SOME GENERAL CONSIDERATIONS ON THE PRODUCTION OF SOLID SMOKELESS FUEL, CHAR AND FORMED COKE FROM NON-COKING COAL.

Anthracite (and in a measure "lean coal") is a naturally occurring, virtually smokeless fuel of comparatively low reactivity. In South Africa as well as in the export market, South African anthracite has been in demand mainly as domestic fuel, and size specifications

(sizes .../

(sizes ranging from about large nuts to peas) are stringent.

In the production of these size grades the quantity of undersize formed is high and as the demand for this material is small the price of the saleable products is much higher than that of bituminous coal.

The present total production of sized anthracite is far too low to satisfy the potential demand for solid smokeless fuel for domestic purposes even in the larger cities of the Republic and it is doubtful whether the demand could be met even if more anthracite collieries were opened up. (The known reserves of the better quality anthracite are limited.)

Although anthracite was used as carbon reductant in blast-furnaces, e.g. in the United States of America the natural product cannot be considered to be strong enough to be used as such in the modern blast-furnace. Its use does not seen to be favoured in the electro-metallurgical industry either, except perhaps in relatively small proportions (too high volatile matter content and too low reactivity).

This naturally occurring, reasonably low-volatile material cannot, therefore, provide a solution to the problem.

As an alternative one can consider the briquetting of anthracite fines. Using some 8% of pitch as binder a briquette of adequate strength for domestic purposes can be made, but unfortuanately such briquettes do not burn smokelessly in conventional appliances.

To render them smokeless they must be subjected to at least an oxidation treatment at a temperature of $250^{o}C$ to $300^{o}C$.

The anthracite briquettes may be made much harder by carbonising them at high temperature ($800^{o}C$ to $900^{o}C$). A product results which may be considered to have adequate strength for blast furnace use. It would have to be determined whether its other properties are satisfactory.

The ..../

The advantage of this raw material would be that a two stage process (briquetting and final heat treatment) might suffice. Unfortunately the available quantities of raw material, having an attractively low ash content are limited.

The third alternative is to use bituminous coal as raw material. The non-coking, bituminous coals that come into consideration have a relatively high volatile matter content.

The simplest treatment to which such raw material can be subjected to produce smokeless fuel or char is to carbonise a suitable size grade (e.g. nuts) after washing the coal to reduce the ash content.

The lumps would retain their shape more or less but as an appreciable proportion of the substance is lost as volatile matter in the process, one must expect that strains will be set up and that shrinkage cracks will develop. The char produced may, therefore, be expected to be relatively weak and a high proportion of fines may be formed even during handling at the carbonisation plant.

This has actually been the experience at plants such as the coker-stoker installation at Messrs. Rand Carbide Ltd., Witbank, the Lurgi plant at Messrs. African Explosives and Chemical Industries Ltd., Modderfontein, and also during the experimental work done at the Johannesburg Gas Works. Further breakage can be expected to occur in transit and such char may not be a very popular household fuel, although if properly prepared, it is a reactive fuel that will burn satisfactorily even in open fire grates.

The electro-metallurgical industries have found this char suitable for their purposes but have, so far, preferred a char having a low volatile matter content (1% - 3%), while for domestic purposes the devolatilisation of the coal should not be carried so far and a volatile matter content in the char of some 12% may be considered to be essential, otherwise the char may not be sufficiently reactive.

The optimum .../

The optimum charring conditions will still have to be established but it would appear that these will differ for the production of carbon reductant on the one hand and domestic fuel on the other hand.

In other words the two markets could probably not be served by carbonising coal under a given set of conditions hoping to sell the larger size fractions of the char for domestic purposes while the smaller sizes would be sent to electro-metallurgical plants. Research will have to be done to determine optimum carbonisation conditions as well as the possibility of producing, simultaneously, for the two markets.

Such char is certainly far too weak to be considered for blast-furnace use.

A more acceptable domestic fuel could be made by forming either coal or a char made from it into some uniform shape (briquetting or pelletizing). Such shaping would also be a prerequisite for the manufacture of a metallurgical coke substitute from non-coking coal. Some binding material would be needed in the process even if it were merely required to make the formed shapes handleable until they could be suitably hardened.

Briquettes made from bituminous coal will not burn smokelessly in conventional domestic appliances and they must therefore be heat treated to render then smokeless.

For form-coke production a final, drastic heat treatment would be essential to give the product adequate strength.

The question now arises whether the coal should be carbonised before shaping (accepting a final heat treatment step) or whether it could first be shaped and should then receive a heat treatment which would serve both as a devolatilisation and as a hardening treatment.

The general opinion seems to be that preliminary charring is desirable. This opinion is founded on the fact that coal shrinks during carbonisation. This shrinkage occurs mainly in the temperature range 400°-500°C.,

at which .../

(at which most of the volatile matter is expelled) and to a lesser degree above about 750°C (secondary shrinkage). Now it is held that, if briquettes made from high volatile matter coal should be carbonised, the shrinkage occurring in the coal at 400°-500°C will cause the briquettes to crack and their strength will be impaired even if the final carbonisation temperature exceeds 900°C. On the other hand, briquettes made from char made at say 600°C would experience little shrinkage during high temperature carbonisation and should therefore yield much stronger briquettes.

Some of the results obtained recently on the carbonisation of pellets in Germany suggest that one should perhaps not be too categorical on this subject. It will have to be established by systematic research what procedure must be adopted to yield optimum results.

Should preliminary charring be necessary, this should be done at the lowest temperature that will have the desired effect (e.g. to reduce the volatile matter and the shrinkage to acceptable levels) so as to avoid making the char too hard and therefore abrasive. Otherwise the wear of equipment such as briquetting presses may become excessive.

All the consumers considered here would require a product of fairly low to low ash content. In fact, one can conclude that the interest of metallurgical industries in such formed material would depend in a high measure on whether it can be offered at a substantially lower ash content than the metallurgical coke presently available.

SUMMARY:

It is apparent from the above analysis that in a plant set up to study how non-coking coal should be processed to produce smokeless fuel and acceptable reductant, provision should be made for:

1. Coal washing;
2. A heat treatment at comparatively low temperature;
3. A forming process (pelletizing or briquetting)
4. A final heat treatment or process capable of

carbonising particulate material (diameter 1" to say 3") at a temperature of up to 900°C.

The available coal preparation pilot plant would satisfy all the requirements envisaged under Item 1.

It could also provide crushing, screening and, to some extent, raw material storage.

If, however, the new plant should have to operate continuously it may be advisable to provide some separate unloading, crushing, screening and raw material storage facilities.

PROPOSALS FOR AND THE COST OF A PILOT PLANT.

Based on the general considerations summarised in the preceding chapter, further literature studies and enquiries were made in various countries. Facets of the problem were studied by officers of the Institute who visited Europe and the United Kingdom in 1964 and the United States of America in 1965.

Professor Dr. W. Reerink, Director of the Research Centre of the Steinkohlenbergbauverein (Essen, Western Germany) was also invited to visit the Republic to obtain first hand information on the conditions in the Republic and to advise on the requirements and the choice of the plant.

A sub-committee of the Fuel Research Board's Pilot Plant Advisory Committee studied the project in detail and their report was finally discussed by the full Pilot Plant Advisory Committee.

The final recommendations of the Committee were approved by the Fuel Research Board as a useful basis for further negotiations.

The motivation for the recommendations may be summarised as follows:

1.Units Required ..../

1. Units Required in the Plant.

In its deliberations the sub-committee came to the conclusion that of the three objectives of such research viz.: the production of smokeless domestic fuel, char for electro-metallurgical purposes and form-coke, the form-coke production would call for the most elaborate plant and also for the most drastic treatment, at least in terms of the carbonisation temperature in the final heat treatment. If facilities were provided for form-coke production the requirements for the other research would also be met.

Furthermore, bearing economic and other conditions - as set out earlier in this report - in mind, it appeared that there is most urgency to obtain information on the possibilities of form-coke production from South African raw materials.

In this case, especially, a low ash content in the final product is desirable. This would have to be borne in mind when chosing the coal to be used. It should be amenable to washing to a low ash content and a relatively low volatile matter content in the coal may be advantageous.

In order to achieve the low ash content at reasonable washery yield, it may be necessary to start off with a product of small size, e.g. duff or pea-duff or to crush the coal to a fairly fine size before washing and this would have to be borne in mind when choosing the primary carbonising equipment.

No extra washing facilities would be required, however, as all the necessary equipment is available at the Coal Preparation Pilot Plant.

In order to cover all the possibly needed process steps, provision should, however, be made in the new pilot plant for a primary heat treatment, for some forming process, and for a final heat treatment, possibly also for drying of washed fine coal.

(a) The Primary .../

(a) The Primary Heat Treatment.

Quite a variety of carbonisation processes is available and attention was given to most types.

For the first stage carbonisation, a carboniser is needed that can deal with fine material. Internally heated retorts such as those of Lurgi and Otto as well as the carbonisers of the Coker-stoker type could, therefore, not be used in this stage. Secondly, flexibility in operation is desirable. One should be able to vary the carbonisation conditions at will to produce chars ranging in volatile matter content from, say, 12% to 1%. The product should be carbonised uniformly to the desired volatile matter content.

These conditions can probably be met in a fluidized bed carboniser, in entrainment carbonisers (Blasverkokung) or by using an American pan-cake type of carboniser.

(b) The Forming Process.

For the time being the attention was confined to a double roll-type of briquetting press with its necessary ancillary equipment. A segmented roll-rim was preferred as this is more wear-resistant and would enable one to change the equipment easily to produce other shapes or to replace it when worn.

Hot-briquetting was not considered at this stage as there is some doubt whether South African non-coking coal would at any stage of heating become sufficiently plastic to produce a coherent briquette during hot pressing. (This does not exclude laboratory work to establish the possible hot-briquetting of non-coking coal and coking coal blends.)

(c) The Final Stage Carbonisation.

The carboniser used in this stage must be able to treat briquettes or coal of say up to large nut size (say a maximum size of about 3").

It would .../

It would be necessary to carbonise at temperatures of up to 900°C (say from 500°C to 900°C). For domestic fuel hardening (possibly also for electrometallurgical carbon reductant or foundry coke) the hardening process could be done at even lower temperature (300° -350°C) in a slightly oxidising atmosphere.

For this step, retorts of the Otto - or Lurgi-type (possibly the pan-cake type) were envisaged, as also the sand-bed carboniser of Inichar, Belgium.

Dr. Otto & Co claim that their retort can be operated at temperatures up to 800°C or 900°C and the Lurgi retort can certainly operate at such high temperatures. There is no assurance as yet that the sand-bed oven can be operated at high temperatures (but the oven appears to be very suitable for the low-temperature hardening treatment).

Provisionally preference was given to the Otto retort, the choice being partly influenced by the fact that commercial plant of this type is to be installed in South Africa.

2. <u>The Capacity of the Plant</u>.

Much thought was given to the desirable capacity of the plant.

In order to prove any type of experimental form-coke it should be tested in a blast furnace. It would, of course, be entirely impracticable to think of producing enough form-coke in a pilot plant to do such a test in a full sized blast furnace.

The United States Bureau of Mines and United States Steel Corporation of America have both proved, however, that reliable results can be obtained in an experimental blast furnace of about 4 ft to 5 ft hearth diameter. Such an experimental blast furnace would consume about 70 tons of coke per day and may need some 1,200 tons of coke to prove its suitability.

These ..../

These quantities are within the reach of a pilot form-coke plant.

These criteria formed the basis of further deliberations and it was finally decided by the Pilot Plant Advisory Committee to recommend a plant having carbonisers of a capacity of 27 to 30 tons per day (3-shift operation) while the briquetting press should be large enough to deal with the output of the first heating stage in one 8 hour shift.

3. The Cost of the Pilot Plant.

Ideally, one should have alternative carbonising equipment in every heating stage as carbonising conditions may have an effect on the properties of the final product.

However, to reduce the capital cost, the idea of alternative plant may have to be abandoned.

The analysis of the prices of carbonising equipment revealed that these differ little from one type of plant to another in the range of pilot plant sizes. There is possibly some advantage for entrainment carbonisers and sand-bed ovens over e.g. the Otto carbonisers.

The prices vary more widely for briquetting presses. Those with segmented rim are rather more expensive than those with a shrunk-on rim. The advantage of the former, in maintenance and repairs and the ease with which rims can be changed (to produce other shapes) would, however, justify the higher expenditure.

Ancillary equipment would remain very much the same whatever type of press is installed. One might save on this, however, by installing only the barest necessities —

After considering various alternatives, the Pilot Plant Advisory Committee concluded that no useful object would be served by undertaking further detailed planning until there was assurance that the capital requirements for the pilot plant could be found.

The capital .../

The capital requirements were, therefore, worked out on broad lines which, however, were based on the most realistic prices that could be obtained.

In this estimate, provision has been made for only one carboniser in every heating stage:

(a) First Heating Stage:

A retort having a nominal capacity of 1½ t.p.h. is estimated to cost R100,000.

Accepting that essential facilities for unloading, screening and storing of coal must be provided and that the char produced in the first stage must be stored for handling in the briquetting plant during a one day-shift, the total ancillary equipment and handling facilities and simple housing are estimated to cost R44,000 (assuming that separate char-quenching will not be necessary).

The cost for the first stage unit, installed would therefore be : R144,000

(b) The Briquetting Plant:

The more costly type of press with all desirable auxiliary equipment, briquette storage and conveyors - for cooling and for transport to the second heat treatment plant was estimated to cost installed and housed:	R122,000
If a less expensive press is acquired and the equipment is reduced to the barest necessities the cost might be reduced to, say,	R60,000

(c) The Second Heat Treatment Plant:

A Retort of about 1½ t.p.h. would also be required for this stage. As before the cost would be :	R100,000
Provision will have to be made for handling of the hardened briquettes and for storage of the final product. If housed under the same roof as the first stage carboniser the cost of ancillaries is estimated at :	R25,000

Testing facilities will be needed and these plus housing are estimated to cost : R20,000

The estimated total Capital Requirements for the pilot plant would therefore be of the order of:

	More Elaborate Briquetting Plant	Simplest Briquetting Plant
	R	R
1st.Stage Heat Treatment	144,000	144,000
Briquetting Plant	122,000	60,000
2nd.Stage Heat Treatment	125,000	125,000
	391,000	329,000
Add for Contingencies	40,000	30,000
Add for Development	20,000	20,000
Add for Testing and Laboratory	20,000	20,000
Add for Site Preparation	10,000	10,000
	481,000	409,000

If drying and char quenching equipment is to be included, the capital cost of the pilot plant would be about R500,000 or R450,000 respectively, which is about equivalent to the income that could be derived by a special levy of 1 cent per ton of coal sold in the Republic in 1964.

OPERATING COST OF THE PLANT.

To run the pilot plant fairly continuously, it is estimated that a staff of about 24 Europeans (ranging in rank from Senior Technical Officers to Operators) and 4 bantu would be needed.

The estimated total of salaries and wages is R74,000 p.a.

At maximum production, operating 300 days p.a. at 30 t.p.d. the plant would produce 9,000 tons of finished product, equivalent to, say, 15,000 tons of raw coal purchased.

The Estimated .../

The Estimated running costs are:

Delivered cost of 15,000 tons of coal at R2.50 p.t. :	R37,500
Pitch (900 tons p.a.) :	R10,000
Washing cost and discard removal :	R30,000
Maintenance and Stores :	R10,000
Water, Power and Heating :	R15,000
	R102,500
Add Salaries and Wages	74,000
	R176,500

which is roughly R20 per ton of finished product.

(SIGNED) A. J. PETRICK.

DIRECTOR.

PRETORIA.

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