Welding Machines for Electrofusion

by D. Usclat (France)

1. Introduction

The electrofusion technique for the jointing of polyethylene pipes is today internationally acknowledged in the gas industry. Indeed it is the most simple to operate, the most reliable and the most economic technique available [1]. For this reason Gaz de France chose this technique as early as 1975 [2]. Today more than a million* electrofusion fittings have been installed on the gas distribution network in France (for 26,000 km of pipelines*)

The control of the electrical energy applied to the electrofusion fittings is an essential element of this technique.

The studies and experience accumulated by Gaz de France over more than 10 years have led to the development, in collaboration with several manufacturers, of equipment and techniques well adapted to all practical situations encountered.

2. Technique

The electrofusion fitting (coupler or tapping-tee) contains a metal coil which is implanted by injection during manufacture. An electric current passes through the resistor which provides sufficient energy by the Joule effect to melt locally the polyethylene of the pipe and the fitting. After cooling, perfect cohesion of the assembly is obtained.

It is still difficult today to explain exactly the physico-chemical processes that occur during fusion between two polyethylene materials. The mechanism of molecular diffusion seems however to be the most important process and this hypothesis has now been confirmed experimentally [3].

This study demonstrates in particular that to guarantee effective molecular diffusion, the parameters which determine the phenomenon must have correct values, in particular the temperature-time variable couple.

The joint is good if the depth of penetration is sufficient, i.e. if the surfaces have been in contact at high temperature for a given time.

In order to obtain a good joint by electrofusion, it is not merely sufficient to supply a certain overall quantity of electrical energy. At each instant(t) of the appropriate fusion time(ts) the correct electric power[P(t)] must be provided.

However, the electrofusion technique presents a certain flexibility as there is no optimum diffusion state, but a relatively wide range within which the joint obtained is satisfactory.

It may be assumed that a correctly designed fitting will accept, without any deterioration of the joint, variations in power [P(t)] of fusion time (ts) as long as their cumulated effects do not cause the overall fusion energy (Es) to deviate by more than ±10% of its nominal value.

This flexibility makes it possible to accept, within certain limits :

- either the inevitable fabrication tolerances of the fitting (value of electrical resistance).
- or the accuracy of the adjustment of power and fusion time by the welding machine.
- or the temperature variations of the fitting due to the weather conditions on the site.

2.2 The limits

In order to specify the limits, it is necssary to study in detail these different variations and to take account of the fusion method used (predefined parameters or self-regulation).

2.2.1 Fabrication tolerances of the fitting

At present, as regards the fabrication of the electrofusion fittings the tolerances on the value of the electrical resistance are generally equal to ±5% of the nominal value.

Narrower tolerances are possible, but they would involve the considerable extra expense of determining very accurately the length of the electric wire, its cross section and its resistivity.

2.2.2 Accuracy of the welding machine

The electricity sources which are generally used(mains or independent generator driven by a thermal motor) are often prone to variations of both voltage and frequency. Variations of ±10% from the nominal value are common.

Moreover, depending on the type of metal wire used, the electrical resistance of certain fittings increases when they get hot (e.g. for a high resistance pure copper wire, the resistivity increases by 110% when its temperature rises by 300°C).

The welding machine will be designed to take account of these variations (source + charge):

- either by altering the fusion time in order to compensate for the induced variations in P(t). This method of adjustment has the disadvantage of linking the fusion parameters of the fitting to the design of the welding machine, which excludes all simple interchangeability possibilities (see 3.2).

- either by using an adjustment stage which modulates the power according to a simple predefined law (e.g.adjustment to constant voltage [U(t) = Cte], or constant intensity [I(t) - Cte] or constant power [P(t) = Cte]). The method of adjustment to constant voltage is today the most commonly used. Adjustment is generally by means of thyristors, which maintain U constant within a range of ±2% of the programmed value. In order to measure the energy, a simple clock is then sufficient. An accuracy of within one second is easy to obtain for low fusion times, i.e. a fusion time tolerance of around 1 to 2%.

2.2.3 Temperature variations

The initial temperature (i.e. before fusion)- of the joint may vary considerably (from -10°C to 45°C as regards the sites in France) depending on the weather conditions on the site and on whether the pipe is exposed to the sun.

The fusion energy must be corrected to take account of the large temperature differences which may exist from one joint to another With the material manufactured today, the energy supply must be corrected by between 0.4 to 0.7% per °C, depending on the design of the fitting.

2.2.4 Welding with the "predefined parameters" method

The fusion method is the most widely used at present as it is the most practical to apply. The optimum parameters [P(t) and ts)] for the fusion of the fitting at an initial temperature of 20°C are determined by laboratory tests.

On the site, the fitting is fused using machines which are adjusted according to these parameters (which are normally the voltage and the fusion time) and to which it is necessary to add the correction of one of these parameters (generally time) to take account of the initial temperature of the joint.

When this fusion method is used, the operator must measure the temperature of the fitting. If only the ambient temperature is measured (e.g. using a probe built into the welding machine) bad welds may result when, for example, the fitting and the welding machine are not exposed to the same temperature.

2.2.5 Fusion with the "self-regulation" method

This fusion method makes use of the possibility of stopping the fusion process when the matter at the pipe-fitting interface is at a sufficient temperature and correct pressure.

The technique has been studied in collaboration with an electrofusion fitting manufacturer and it is used for the entire range of innogaz fittings.

Figure 1 shows the operation of this type of fitting : a highly localized displaement of matter is detected by a sensor which transmits the information concerning completion of the fusion to the machine. The machine then automatically cuts off the electricity supply. The sensor is built into the connection lead.

In this technique, the state of the matter in the vicinity of the interface, which is an essential parameter of a good fusion, forms part of the regulation loop which controls the fusion.

The curve in Fig.2 shows that the fusion time is automatically corrected when the electric power varies. Similar curves are obtained according to the initial temperature of the joint.

This system therefore acts as a very accurate energy regulator, capable of providing energy to within 10% of the ideal fusion energy requ-

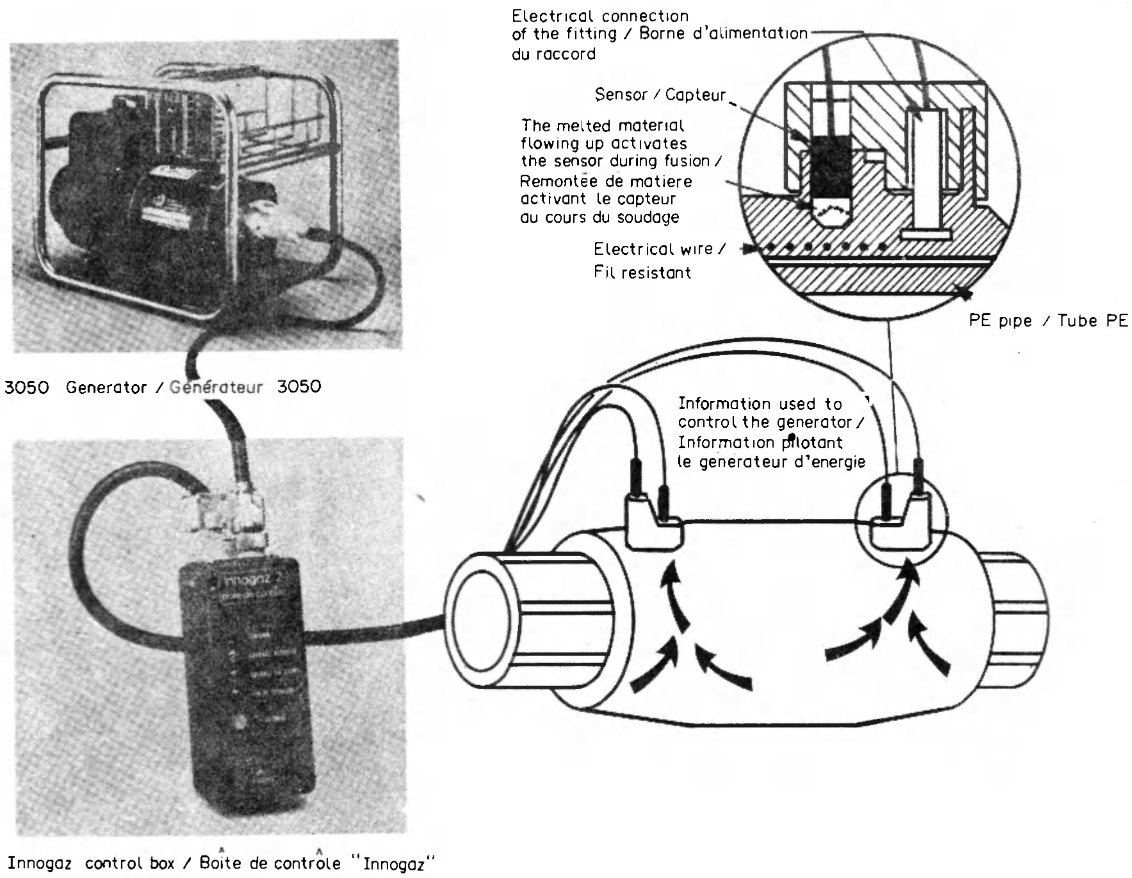


Fig.1. Self regulating fitting.

ired while accepting considerable variations in power (±25%) and carrying out automatic temperature correction.

3. The welding machine

3.1. Design and accuracy

The design and accuracy of a welding machine depend on the type of fitting used and on the conditions in which it is to be fused. Tables 1 and 2 present different possible cases.

In the "predefined parameters" fusion mode (Table 1) it can be seen that under certain circumstances it is not necessary to correct temperature, as long as (case No.1) :

- high precision materials are used (e.g. ± 1% on the electric resistance (R) of the fitting and on the voltage regulation (U) of the welding machine).
- the temperature differences between two joints on any site do not exceed 20° C.

These conditions are costly and unrealistic (particularly as regards the temperature). We, therefore, prefer the second solution; (case No.2) which is better adapted to the requirements of industrial manufacture (tolerance for R: ±5%, tolerances for U, or I:±2%) but which results in the need for temperature correction. However, it may be noted that this correction does not need to be highly accurate and the temperature measurement may be carried out to ±5°C.

The "self-regulation" fusion mode (Table 2) has many advantages, as the fusion energy is always perfectly controlled (with ±10%) even though there are significant variations in power (±25%) and temperature (-30°C, +60°C)

Requirements for materials are therefore low (e.g. +5% for the electrical resistance of the fitting and ±10% for the voltage or current from the welding machine), and of course, the joint can be fused at any temperature without any need for its measurement.

3.2 Universality and interchangeability

Today the fittings used are fused using machines specific to each brand, or universal machines.

The use of universal machines has many advantages :

- possibility, at any point in time, of choosing the best fitting at the best price.
- guaranteed supply of fittings.

Of course, these universal welding machines, which must be adjustable to different types of brands of fittings, involve slightly higher investment costs.

3.3 Electricity and safety

In order to use electric energy in the trenches on site, which are generally very wet, it is necessary to respect the normal safety precautions to avoid electric shocks.

Three categories of voltage are defined in the international standards (0-24, 25-48, ≥48V) and the degree of protection depends on the voltage category of the system used.

The category 0-24 V does not call for any special protection. However, these low voltage require high intensities (around 100A) for large sleeves (dia.200 mm) which require a fusion power of around 2 kW.

Systems which operate in the category 25-48 V, with the usual safety precautions (doubly insulated leads, protected electric connection terminals), are therefore chosen in preference.

3.4 Standard or specific generators

When a connection is made with the mains or on a standard generator (110 or 220 V), a unit to adapt the voltage level should be placed behind the source.

A transformer is a simple and safe solution. Its major drawback is that it alone consumes a large proportion of the power available at the start. In consequence, in order to fuse 200 mm diameter pipes at 2 kW using a mains or standard generator power supply, the companies must be equipped with powerful generators -- which are very costly -- capable of supplying at least 3 kW.

The use of a specific generator, whose alternator is specially designed to supply the right amount of current or voltage results in transformer savings and in a reduction in the power and hence the size of the generator required.

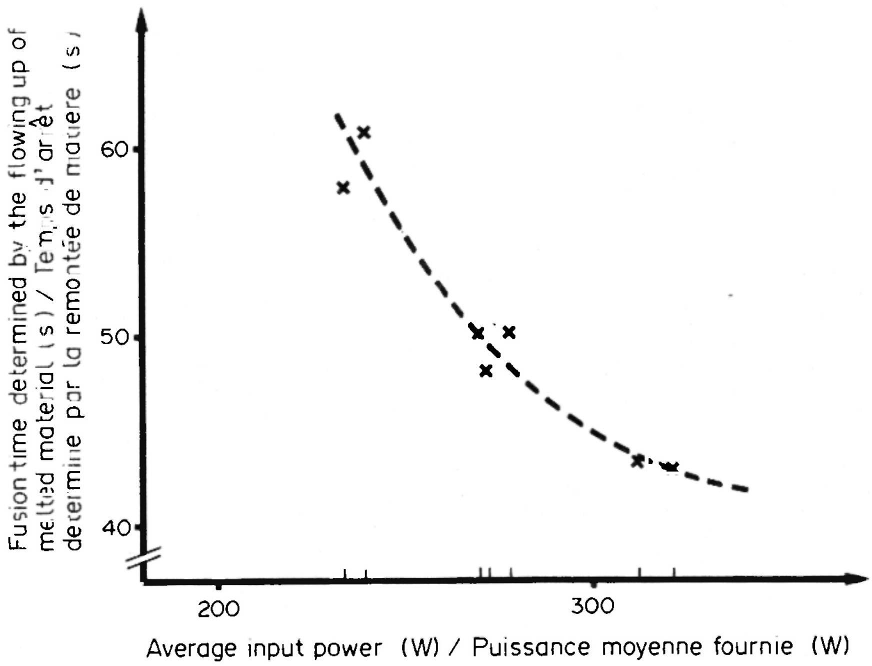


Fig.2. Self regulating of the fusion time.

Table I

Electrofusion in predetermined parameters mode

	Variation in fusion energy Case No.1	Case No.2
Fabrication tolerances of the electrical resistance of the fitting	±1%	±5%
Tolerances on the control of energy supplied by the welding machine	±3%	±5%
e.g. for a weld at constant voltage	±1%	±2%
tolerances for U (ΔU)	±1%	±1%
tolerances for t (Δt) = $\Delta E_2 = 2\ \Delta U + \Delta t$		
Total	±4%	±10%
Admissible maximum	±15%	±15%
Available energy variation = acceptable initial temperature difference without energy correction	11% 20 to 25°C	5% 10°C

Table 2

Electrofusion in "self-regulation" mode

	Effect on fusion power
Fabrication tolerances of the electrical resistance of the fitting	±5%
Tolerances for the control of power supplied by the welding machine	±20%
e.g for a weld at constant voltage tolerances for U (ΔU)	±10%
Total	±25%
Admissible maximum (for power)	±25%
Tolerances for energy (according to the accuracy of the sensor)	$<$±10%
Admissible maximum	±15%
Initial acceptable temperature range	-30°C, + 60°C*

* This range is theoretically limitless. Satisfactory results were obtained over the range -30°C, +60°C with the Innogaz system.

4. Solutions

After reading the paragraphs above it is easy to understand that the construction of a welding machine requires considerable reflection in order to determine the parameters to be retained.

Gaz de France has become involved in this reflection process, in collaboration with certain manufacturers, and has thus defined a set of materials and equipment corresponding to the diverse requirements of the companies who carry out electrofusion process.

4.1 The "Julie" system

This system, developed by J.Sauron S.A., was designed for companies who wish to work automatically with several brands of fitting, operating with the "self-regulation" or "predefined parameters" method, using a standard or specific generator. The concepts of universality and automation of adjustment have been made compatible by associating with the welding machine a light pen which acquires the information necessary to the adjustment of the machine. This information is contained in a bar-code, on a label attached to each fitting (Fig.3).

The control box "Julie" controls, according to the information read by the light pen :

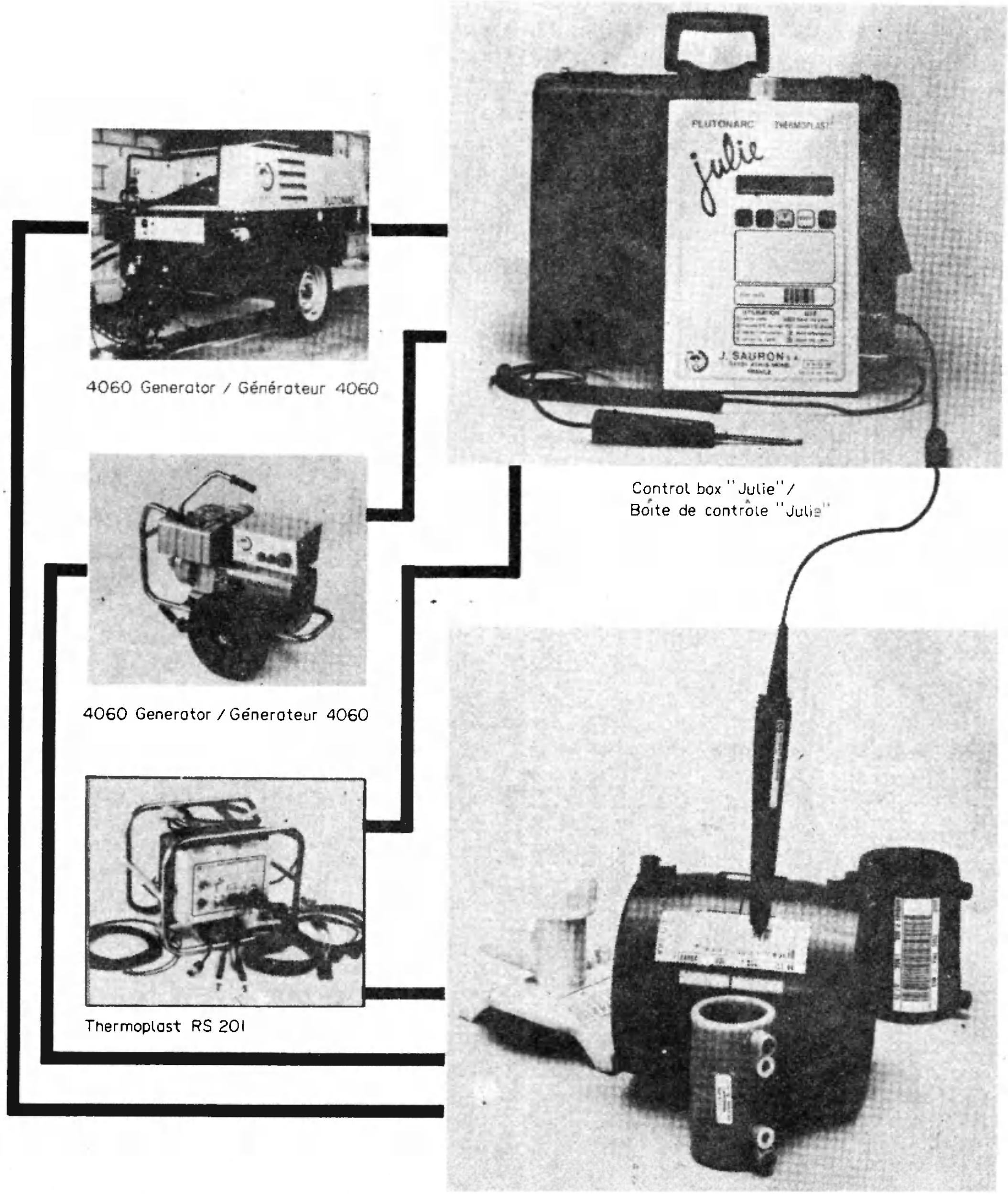
- either an interface, the Thermosplast 201, comprising a transformer and a regulation system capable of using the energy provided by the mains or by a standard generator.
- or a specific generator, the 4060 generator, equipped with a regulation unit which, directly controlled by "Julie", supplies any desired level of current or voltage.

The universality of the system is total, as it operates both at constant voltage or intensity and at constant power. The "Julie" system can therefore accept all brands and types of fitting, existing now or in the future. To be able to fuse a new fitting, it is simply necessary to print the label containing the corresponding adjustments.

The "Julie" system operates equally well in the "predefined parameters" mode and the "self-regulation" mode.

In the "predefined parameters" mode, a thermometer probe directly connected to "Julie" measures the temperature of the joint. The information is then used directly to correct automatically the fusion energy according to the correction law relevant to the fitting. The parameters of this law are acquired from the information contained on the bar-code of the label.

In the "self-regulation" mode, the information in the bar-code provides the correct voltage



level (between 0 and 48 V) and current level (between 0 and 100 A). The sensor in the connection lead then takes over to define the fusion time.

4.2 The Innogaz system

A company which decides to use only fittings which are fused using the Innogaz system (self-regulation at a voltage of 39V ±10%) can work with a light and compact fusion kit for, as we have seen, the system has few requirements as regards accuracy of power settings, and the energy regulator is limited in practice to a sensor placed in the connection lead.

The control box which can function at a voltage of 50 to 60V at any given power, can operate:

- either on a standard generator (or mains) coupled with a simple transformer.

- or directly on a small specific generator, simple and easy to handle (Fig.2), specially designed for this application. This generator is designated as 3050.

4.3 Modular solutions

The control box Innogaz combined with the 3050 specific generator (light, compact, economical) are ideal for any company using self-adjusting fittings at 39V (Innogaz products).

For a company launching into electrofusion and planning to use different brands in the long term, it is of course not always possible to invest from the outset in the "Julie"/4060 specific generator set. On the other hand, they could start up with an Innogaz control box and a simplified version of the 4060 generator in order, later on, to adapt the generator and to acquire a "Julie" control box so as to be able to use other brands while conserving an entirely automatic fusion procedure.

5. Conclusion

Simple and effective, mono-voltage (36-42 V) self-regulation appears today to be the ideal system to choose.

This progress is integrated in the "Julie" system which is nevertheless capable of fusing the oldest products (predefined parameters, multi-voltage or current). It today constitutes the ideal tool for any company which wishes to remain free to choose the fittings to use while benefitting from entirely automatic fusion procedures.

Doc.IIS/IIW-907-86 (ex doc.XVI-5-5-86) submitted to Commission XVI "Welding of plastics" of the IIW.

Mr.D.Usclat works for Gaz de France, 361 Avenue du President Wilson, BP,33,932211 la Plaine St.Denis Cedex, France.

Ammendment of Subscription Rates for IIW Membership

For quite some years, the subscription rates for the IIW membership, have been kept low although the costs of administration, postage, publication of the Indian Welding Journal etc., increased steadily causing concern.

In the 160th Council Meeting, it was decided that, with effect from 16th April, 1987, the subscription rates for different categories of membership will be amended as follows :

Membership Category		Entrance Fee (Rs.)	Annual Subscription (Rs.)
Industrial	Class I	2000/-	2000/-
Corporate	Class II	1000/-	1000/-
Member	Class III	500/-	500/-
Fellow		100/-	100/-
Member		85/-	85/-
Associate Member		70/-	70/-
Associate		40/-	40/-
Student		30/-	30/-

Annual subscription notices for the year, 1987-88 will be sent to all members accordingly.

In this Council Meeting, it has also been decided to introduce a scheme for Life Membership for the individual Corporate Members i.e. Fellow, Member & Associate Members. The rates of subscription for Life Membership for Corporate Members as decided, are given below :

Fellow	Rs. 800/-
Member	Rs. 700/-
Associate Member	Rs. 600/-

The scheme for Life Membership of IIW offers not only the advantage of paying the subscription at one time and forget it for a lifetime but the opportunity to save on a long term also.

Interested members may write to the Hony. Secretary of IIW for further details.


KEARC
WELDING EQUIPMENTS
&
SYSTEMS
The expanding expertise. The widening range.
Automatic Submerged Arc ASA-1
Semi-Automatic MIG/MAG
Welding Positioners
Column & Boom
Rotators
TIG
Pulse TIG
MIG Torch
our range also includes
• Air & Oil cooled Single, Double & Multi-Operated Welding Transformers
• DC Welding Rectifiers
• Motor Generators
• TIG & MIG/MAG Welding & Carbon Arc Gouging Torches, Energy Saving Device, Flux Recovery Systems etc.
&
• Custom built Welding Systems
SGS/KEPL/8/86
At KEARC we have 30 years of experience in welding & cutting technology behind us.
All our equipments from Transformers, Rectifiers to our sophisticated Semi-Automatic MIG/MAG & Automatic Submerged Arc Welding incorporate excellent design features, versatility & ruggedness.
Make KEARC your first choice for that 'PERFECT WELD'.
KANUBHAI ELECTRICALS PVT. LTD.
Sir RNM House, 5th Floor,
3B Lalbazar Street,
Calcutta 700 001.
Phones:
288507 • 288508 • 282283
Telex: 021-3532.
Gram: INDENTERS
Branches at:
BOMBAY
DELHI
MADRAS
Write to us today at Kanubhai Electricals Pvt. Ltd.,
117 Bajaj Bhavan, Nariman Point, Bombay 400 021.
We are interested in details of KEARC Welding Equipment
for the following application/s.
Name
Designation
Company Address