The present invention relates to a method of attaching end pieces and other surrounding pieces of stock, hereinafter referred to as stock, onto wire cable and wire ropes, hereinafter referred to as cable.

The main object of my invention is to produce a reliable union directly between such stock and cable.

In one of the methods used up to now the union between a smooth bored piece of stock and the cable is effected by subjecting the stock to a considerable number of light blows in a rotary swaging machine.

In another method a similar union is effected between the cable and a piece of stock having a rough bore, produced by cutting a thread, by giving a series of dead blows to the stock in a dead stroke mechanical press until the dies come together.

The general aim has been to cause the metal of soft and malleable stock to flow into the helical V spaces between the wires of the outer shell of the cable, and processes heretofore adopted have produced a more or less satisfactory union for resisting fairly low parting forces, but so far as I am aware it has not been possible with known methods by mass production uniformly to produce good unions which will withstand a determined high parting force, such as a pull in the neighbourhood of the breaking point of the cable.

The usual method in the case of a rotary swaging machine is for the operative manually to insert the sleeve and cable into the machine, or in a fixed press to introduce the sleeve between the dies and periodically to turn the sleeve to be acted upon so that it can be given successive blows in different radial positions of the stock.

Where a piece is subjected to a large number of comparatively heavy blows from different radial directions the tendency is to produce ovality of the stock which ovality changes its direction or major axis with each blow, and a great number of blows can be given to the sleeve without necessarily ensuring a good joint. Moreover, in neither the mechanical dead blow presses hitherto used, nor in the rotary swaging machines according to known methods, is it practicable in mass production methods to determine that the stock will be subjected to a desired closing pressure.

Experience of both of the above methods and their disadvantages shows that they are not reliable enough to conform to high standard requirements, and particularly where each attachment has to be tested to withstand a test load which is near to the breaking strain of the cable. Under such a test the percentage of failures with the aforesaid methods of attaching pieces of stock to cables has been considerable.

The known methods heretofore referred to have also failed to establish uniformly that friction grip between the outer and inner shells of the cable which is necessary to prevent relative slipping of such shells when the cable is under load and consequently it has been usually necessary to weld the wires of the cable together at the ends.

Furthermore, if many blows are given to the sleeve the material thereof is liable to suffer from work hardening and become too elastic for the purpose hereinafter described.

In some of the methods referred to above it is stated that pressure may be used in place of swaging or hammering, but no directions are given as to the extent of the pressure to be applied.

It has also been proposed to attach the stock by means of intermediate pieces, which may be continuous or in the form of coils. Such methods involve the use of an additional part, which involves inter alia extra trouble, and an additional complication where mass production is in view.

I would therefore have it understood that this specification, and the claims hereof, do not include methods where such intermediate parts are used. Nor do I include the use of such great pressures in relation to the stock used as will produce what is termed "cold welding" of the stock and cable.

The present invention is based on the conclusion that the main factor in obtaining a powerful joint between the stock and the cable is the setting up of a very intense frictional grip between the stock and the cable without deformation of the latter or its strands beyond the elastic limit and without any substantial intrusion of the metal of the stock into the grooves between the strands of the cable and with this consideration in view, the closing pressure to be exerted on the stock to produce a union to withstand a given parting force can be determined in relation to the resistance of the stock to compression and the coefficient of friction between the parts, and if the final pressure is restricted to the limit so determined consistent results can be obtained when the materials used are similar, i.e., successful mass production becomes practicable, which has not heretofore been the case.

The present invention broadly consists in applying the stock to a cable and forcibly closing the stock around the cable by a gradual pressure and restricting the final pressure to a predeter-
minded magnitude which will give a union of desired strength in the aforesaid manner so that there is an intense frictional grip established between the stock and the cable. The application of hydraulic pressure is preferred, applied by a hydraulic machine having provision for limiting the final pressure exerted so that the sleeve is subjected to a final closing pressure in accordance with that which has been previously predetermined to be suitable to obtain a union of the desired strength. Other means of applying the pressure to a fixed limit, such as through a balanced liquid column, a gaseous fluid or a spring, may be adopted.

I have further discovered that there is a definite relationship between the co-efficient of friction, the resistance to parting which the stock must withstand, and the loads which are necessary (a) to deform the stock to a certain extent in the absence of a core or of the cable, and (b) to deform the stock to the same extent around the cable, subject to an allowance for friction losses in the machine by which the pressure is applied, which losses can be represented by a constant.

Therefore, being given the maximum parting force to which the cable will be subjected, the aforesaid co-efficient of friction and such constant, then by first ascertaining the pressure which is necessary, in the absence of a core, to bring the stock down to the diameter it is finally to take up when compressed on the cable, the pressure which is to be exerted on the stock in order to achieve a union of a predetermined strength can be established. I do not however restrict my invention to cases in which the pressure is obtained mathematically, for it may be obtained by trial and observation.

In attaching end or intermediate pieces of stock onto wire cable and wire ropes according to the present invention the metal chosen for the stock is softer than that of the cable wires to such an extent, and the stock is radially closed onto the cable with a pressure so chosen, as to cause the stock radially to compress the shells of the cable sufficiently partially to deform the softer stock but only to elastically deform the wires of such shells, so that after removal of the pressure the force of the stock to recover its original form is less than that of the harder cable wires whereby such an intense frictional grip is set up between the cable and the stock on the one hand and the respective shells of the cable on the other as will ensure neither the stock and the cable parting nor the shells of the cable slipping under a predetermined load.

The closing of the sleeve by gradual pressure not only prevents undue deformation but also allows the metal time to flow. By way of example, I arrange that the pressure is applied for a duration of say one-fifth of a second in lieu of the more usual method of imparting a succession of blows of a duration of say one-hundredth of a second each.

I have found that for the best results the applied pressure may be determined by the following formula, viz.:

\[ F_1 = F + \frac{f \times 1.1}{\alpha} \]

where \( F_1 \) is the total pressure applied to the closing die radially to close the stock onto the cable. \( F \) is the total pressure required to be applied to close the die onto a piece of stock in which the cable is not present. \( f \) is the test load below which the attachment must not part from the cable or the cable shells slip on each other.

A co-efficient of friction between the stock and the cable being approximately \( \frac{1}{2} \) between a steel piece of stock and a zinc coated cable.

1.1 is a correction co-efficient for taking into account friction losses of about 10% in a hydraulic press by which the pressure is applied.

I have found that annealed steel containing from .1 to .4 per cent. of carbon and of tensile strength between 24 to 29 tons with a minimum elongation of 25% is particularly suitable for the stock. Satisfactory results will in general be obtained if the steel withstands the following crushing test:

A sleeve of length equalling five times the diameter of the bore, of external diameter equaling twice the bore diameter, is crushed between two flat anvils; there must be no cracks on the corners or in the centre if the steel is to be suitable.

Good results have been obtained using a steel of .2 carbon content and a cable wire of 90 to 100 tons tensile steel having a carbon content between .50 and .60 per cent., manganese 0.50 to 0.70, sil. 0.65 to 0.15, phosphorus under 0.05, sulphur under 0.05. A piece of such a stock of mild steel of five bore diameters in length and of three-eighths of an inch diameter when closed by a gradually applied pressure of 15 tons upon a cable of three-sixteenths of an inch diameter composed of a core of one wire and three outer shells of 8 and 12 and 17 wires respectively, all wires being of high tensile steel as above described, was found to resist a pull of 3238 pounds without separating. On a similar piece of stock to that above referred to being placed between the dies without a cable, a load of 7 tons was required to be applied to the dies in order to make these close together over the socket.

Generally speaking a piece of stock tested as aforesaid and of length=5d where \( d \) is diameter of cable will hold the cable to a load which is given by the formula up to a limit where the elastic reaction of the cable is greater than the resistance of the stock to expansion, this being a function of the thickness of the wall and the tensile strength of the stock.

To recover its original form a given cable, the maximum holding power will be given by a certain final pressure which can be determined as above stated. By increasing the pressure above this figure, the holding power will decrease due to the cable suffering permanent deformation.

The pressure per square inch on the cable is also important. This should not exceed 20 tons per square inch for a piece of stock where \( D \) (outside diameter of the piece) =1.6d, 25 tons for a piece where \( D=2d, 30 \) tons where \( D=2.5d \).

Before therefore applying the formula, it is essential to calculate the pressure per square inch.

This pressure \( P_2 \) is given by the following formula:

\[ P_2 = \frac{f_1 \times 1.1}{dL} \]

Where:

\( f_1 \) is the pulling off load.

\( d \) is the diameter of cable in inches.

\( L \) is the length of sleeve of stock in inches.

Where the stock is in the form of a socket the length above referred to is the length forcibly closed onto the cable.
In my invention it is immaterial whether the bore of the end piece is smooth or rough, since I apply a pressure of such a magnitude and in such a way that the cable secured in the stock by causing a permanent pressure between the stock and the cable which enables the stock to be held to the cable and the shells of the cable to be held to each other essentially by friction. An advantage of this is that not only is an intense friction grip set up between the socket and the outer shell of the cable, but also between the outer and inner shells of the cable, and the tendency for the inner and outer shells to slip relatively to each other is avoided.

In order that the present invention may be more readily understood, reference is hereinafter made to the accompanying drawings, in which:

Fig. 1 shows diagrammatically one form of hydraulic apparatus suitable for carrying out the invention.

Fig. 2 shows an empty sleeve ready for compressing and Fig. 3 a sleeve flattened to test for the suitability of the material. Fig. 4 shows the sleeve being compressed in the absence of a core in order to ascertain the factor F of the formula. Fig. 5 shows a sleeve about to be compressed on the cable and Fig. 6 shows the sleeve when compressed as shown in Fig. 7 is a cross-section through the cable and stock showing the friction grip and lack of penetration of the metal of the sleeve into the grooves of the cable. Fig. 8 shows a pair of dies formed to produce a rough screw thread, the sleeve being shown with the thread roughly formed therein. Fig. 9 shows the alternative form in which six pistons are used to produce a hexagonal shaping of the sleeve when compressed.

In carrying out the method a piece of stock 5 is submitted to a crushing test between two dies 6, 7 (Fig. 2). The material, if suitable, should be capable of being crushed into the form shown in Fig. 3 without cracking at the ends 6.

To apply the pressure to close the stock around the cable 1 I prefer to use a hydraulic press (Fig. 1) fitted with an accurate and adjustable safety valve 2 by which the closing pressure of the die can be readily predetermined and not exceeded.

In order to ascertain this predetermined pressure, a piece of stock 16 of the size to be subse-
dually applied to the cable is compressed in the absence of an inserted cable as shown in Fig. 8 so as to obtain the total pressure P, whereas, if the factors f and the co-efficient of friction are known, the pressure P1 can be readily calculated.

The pressure is applied on a tool consisting as shown in Figs. 2 to 7 of two semi-circular dies 3, 4.

The valve 2 is set to operate at the pressure so determined and the operation of applying the stock to the cables can be carried on without further interruption. Fig. 5 shows a piece of stock 11 about to be compressed onto a cable 12 and Fig. 6 shows the position of the dies when the stock has been compressed to the predetermined degree.

The determined pressure is reached before the dies come together. If the dies were closed to-
gether, the pressure opposing the contracting pressure would depend upon the reaction between the two faces of the dies; whereas this opposing pressure, must be, for the dies when the stock has been compressed to the predetermined degree.

When the pressure is released both the stock and the cable tend to recover their original form, but the tendency of the stock to recover its original form is less than the tendency of the cable to do so, the result being the setting up of an intense friction grip between the stock and the cable and between the shells and the core of the cable.

When the stock has been fully compressed onto the cable, the metal of the stock has not flown into the grooves of the cable, but effects an intense local friction grip on the outer wires of the cable, as shown in Fig. 7.

The flare of surplus metal arising from the closing in of the stock is left, or machined off for appearance sake, or removed by application of a suitable comparatively light blow or steady pressure with the socket in a position displaced through 90° relative to the first.

Separation of the die parts 1, 2 from the stock and uniformity of operation is promoted if the dies parts are lubricated, the use of paraffin wax for this purpose serving well.

While I have referred to the use of annealed mild steel any metal may be used having character-
istics such that after release of the pressure its tendency to recover its original form is less than that of the cable.

Another method of preventing flare is to use a tool such that the pressure transforms round stock into a hexagon the surplus metal then being used to fill out the corona of the hexagon.

It occurs sometimes that the length available for the attachment is so little that the pressure forces the metal of the stock to flow along the cable and the necessary pressure between the stock and the cable cannot be attained. In this event I use a tool grooved circularly, or the most convenient way being to cut a thread in the two dies 3, 4, composing the tool as shown in Fig. 8 before hardening. When the pressure is applied the dies 3, 4 grip the stock 11 transversely and forms a rough screw thread thereon which can readily be finished by using a screw cutting die, and the fact that the thread is nearly made before using the cutting die causes the amount of metal removed to be very small, and so there is little or no reduction of the friction grip which has been produced between the stock and the cable, and the shells and core of the cable.

In general I prefer the length of the stock to be between three and five times the external di-
dameter of the stock.

In a modification (shown in Fig. 9) of the hy-
draulic closing method a circular series of, for example, six tools 14 may be operated by hy-
draulic means, so that a polygon, for example, a hexagon 15 is formed as the result of the simultaneous closure towards the centre of the stock 11. The fluid is conveyed from the source 16 past safety valve 17 through pipe lines 18 to the various cylinders containing the piston tools 14.

The limitation of pressure could be obtained by mechanical means if the pressure is applied between the plunger of the mechanical press and an annular or piston by a spring, rubber, or preferably by a liquid or fluid column under pressure.

Liquid loading may take the form of a loaded hydraulic column opposing liquid under the piston, hydraulic press or hydraulic accumulator fashion, so that the predetermined pressure cannot be exceeded. Stop pressure may be provided to limit the movement of the die or piston mem-
ber when the pressure is reached. The small column of the press may be variably loaded to obtain different balancing loads. A pump may, however, be used with a safety valve or hydraulic accumulator in circuit.
What I claim is:

1. A method of attaching stock to wire cables with reference to the co-efficient of friction ($\alpha$) between the cable and the stock, the maximum parting force ($f$) to which the parts will be subjected and the total pressure ($F$) necessary to deform the stock in the absence of a core, which consists in fitting the stock to the cable and exerting on the stock a gradual pressure so as forcibly to close the stock around the cable into direct intimate contact therewith and controlling the total pressure ($F_1$) exerted on the stock so that such pressure is approximately that given by the formula

$$F_1 = F + \frac{f \times 1.1}{\alpha}$$

whereby to produce an intense friction grip between the stock and the cable without causing deformation of the cable or its strands beyond the limits of elastic recovery or any substantial penetration of the stock into the grooves between the strands of the cable.

2. A method of attaching stock to wire cables with reference to the co-efficient of friction ($\alpha$) between the cable and the stock and the predetermined maximum parting force ($f$) between the stock and the cable which consists in first applying a total pressure ($F$) to a piece of stock to compress the latter in the absence of a core to a predetermined external diameter approximately equal to that to which the stock is reduced around the cable, fitting the stock to the cable and exerting on the stock a gradual pressure so as forcibly to close the stock around the cable into direct intimate contact therewith and controlling the total pressure ($F_1$) exerted on the stock so that such pressure is approximately that given by the formula

$$F_1 = F + \frac{f \times 1.1}{\alpha}$$

whereby to produce an intense friction grip between the stock and the cable without causing deformation of the cable or its strands beyond the limits of elastic recovery or any substantial penetration of the stock into the grooves between the strands of the cable.

RENE TONDEUR.