Aug. 30, 1932. R. RICHTER 1,875,263

SYSTEM FOR STARTING ELECTRIC MOTORS

Filed June 27, 1929 2 Sheets-Sheet 1

Fig. 1

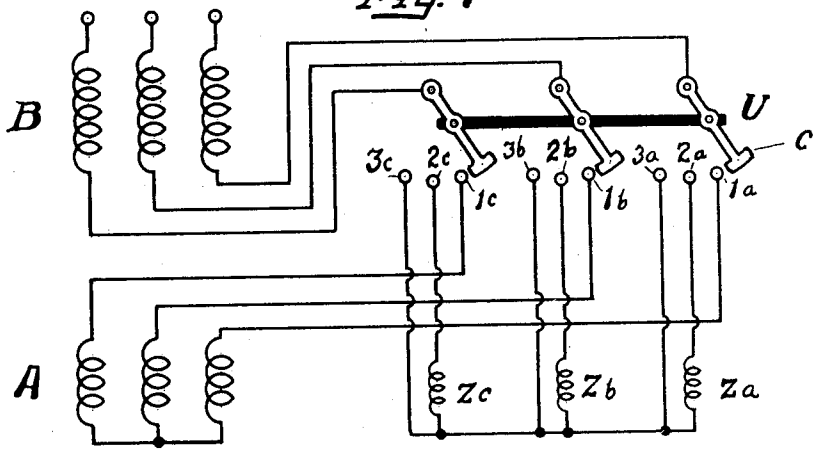



Fig. 2a

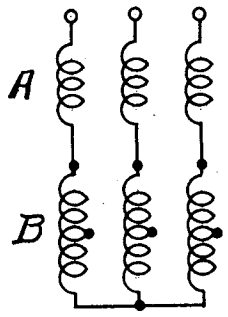



Fig. 2b

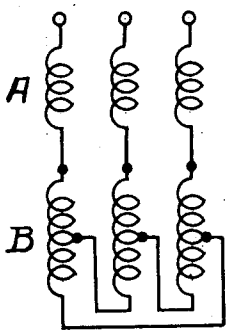



Fig. 2c

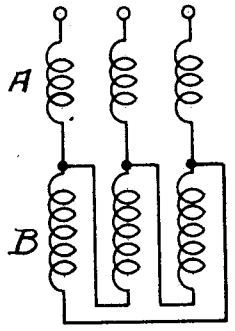
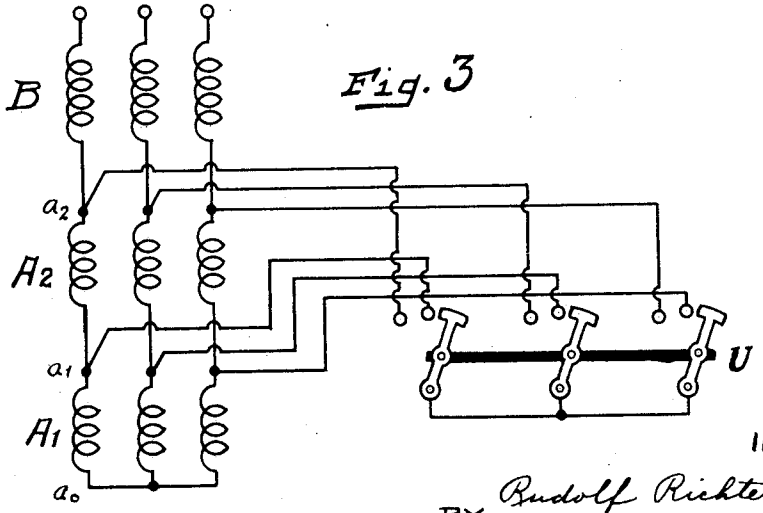



Fig. 3




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Aug. 30, 1932. R. RICHTER 1,875,263

SYSTEM FOR STARTING ELECTRIC MOTORS

Filed June 27, 1929 2 Sheets-Sheet 2

Fig. 4

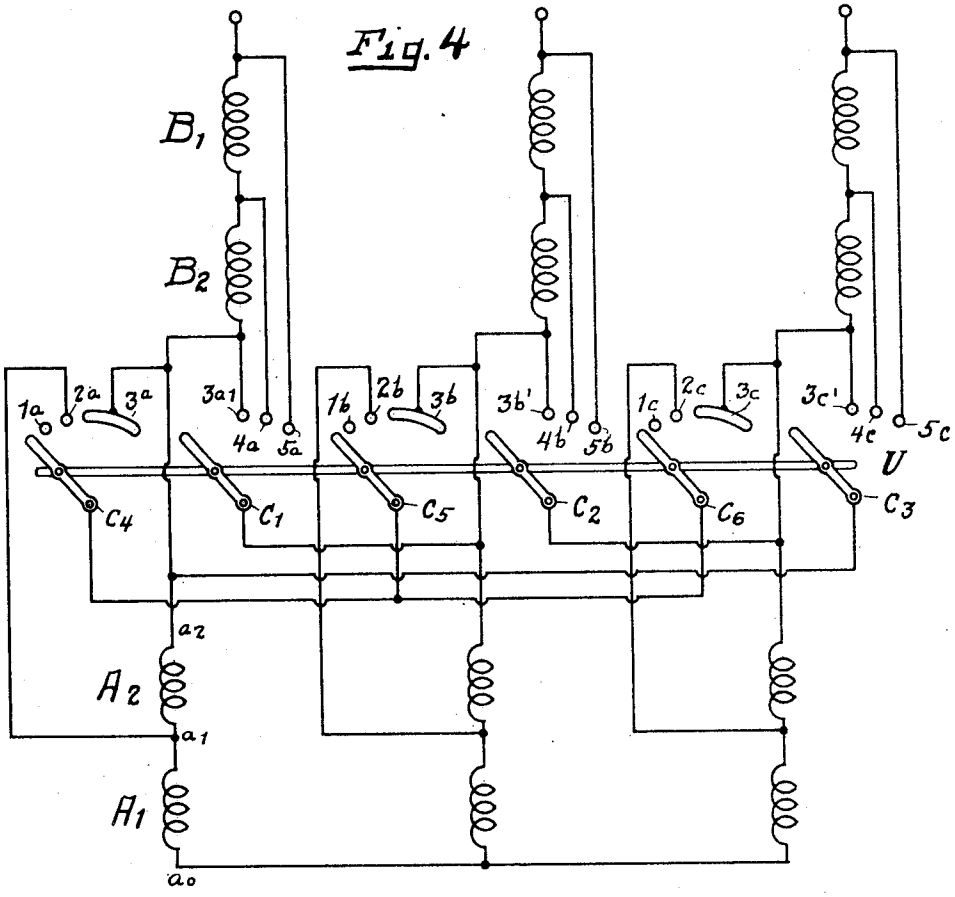



Fig. 5

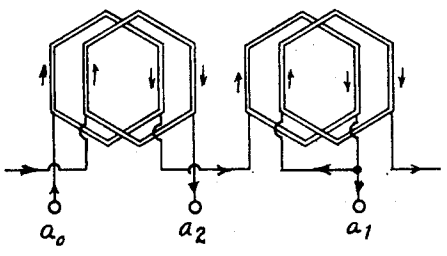



Fig. 6a

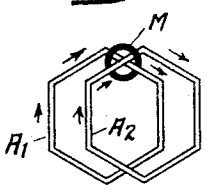



Fig. 6b

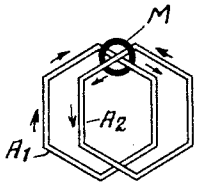



Fig. 7

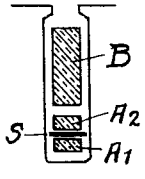
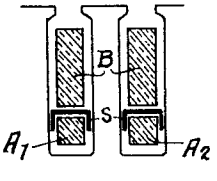



Fig. 8




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Patented Aug. 30, 1932

1,875,263

# UNITED STATES PATENT OFFICE

RUDOLF RICHTER, OF KARLSRUHE-DURLACH, GERMANY, ASSIGNOR TO RADIO PATENTS CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

## SYSTEM FOR STARTING ELECTRIC MOTORS

Application filed June 27, 1929, Serial No. 374,075, and in Germany October 27, 1928.

This invention refers to a method of starting alternating current motors, especially of the type known as induction motors and in particular, motors which have different numbers of poles for starting and working condition.

The object of this invention is to provide connections for starting, but suppress any excessive current thru the windings during the starting period.

Another object is to provide intermediate connecting steps between the starting and the working conditions, so as to make this change gradual.

Another object is to provide for changing one of the windings from the star connection during starting to a delta connection during operation with intermediate mixed connections.

Another object is to provide short circuiting means for the starting winding with intermediate partial short circuiting connections.

Another object is to introduce inductive means in the starting winding to prevent excessive currents in this winding during operating condition.

The invention is fully described in connection with the drawings which are described as follows:—

Figure 1 is a diagram of connections for a starting and working winding, wherein an impedance is introduced in parallel with the starting winding on an intermediate step and a short circuit on the final step.

Figures 2*a*, 2*b* and 2*c* show an arrangement constituting an embodiment of my invention, according to which the working winding is changed in steps from a star connection to a delta connection, in order to prevent an excessive current rush during the transition period.

Figure 3 shows a further arrangement for carrying out my invention, in which a sectionalized starting winding is provided, the individual sections of this winding being short circuited in successive steps during the starting and operating transition period.

Figure 4 illustrates the connection of working and starting windings, combining both circuit arrangements of Figures 2 and 3, wherein the working winding is changed in steps from a star connection to a delta connection, while the starting winding is short circuited in successive steps.

Figure 5 is a diagrammatic representation of two sections of the starting winding corresponding to Figure 2 with the directions of current indicated to explain the operation of these starting windings.

Figures 6*a* and 6*b* show an arrangement of a magnetic inductive circuit, arranged around a part of the starting winding to reduce the magnetic field in the starting winding during operation.

Figure 7 shows the location of such magnetic path in the slots carrying the windings.

Figure 8 shows an alternative arrangement of the starting winding in different slots. Similar reference characters refer to similar parts throughout the different diagrams of the drawings.

It is well known in the art to use, for the purpose of starting induction motors, connections which produce a larger number of poles during starting, and a smaller number of poles during working condition. In my co-pending application Serial No. 193,831 filed May 24, 1927, which has materialized into Patent No. 1,746,445, I have described an induction motor, wherein the number of starting poles is smaller than the number of working poles. It will be understood that the system of starting described in this application, is applicable to either of the two types, provided in each case, there are independent starting and working windings arranged to be consecutively brought into operative condition.

In accordance with my above mentioned United States application, a starting connection for short circuited induction motors is suggested, in which, during starting, an auxiliary winding of smaller number of poles from the operating winding is connected in series with the operating winding. This auxiliary winding is short circuited as soon as the operating motor speed is reached. In case that such starting winding has a higher number of poles than the operating winding,

a current rush takes place at the transition from starting to operating condition. In order to prevent this disadvantage from occurring at the transition from the starting to the operating condition, the transition from starting to operating condition of such motors is carried out gradually across one or more intermediate steps, in accordance with my invention. Such intermediate steps may be obtained, for instance, by short circuiting the starting winding at first across ohmic resistances or eventually inductive impedances instead of carrying out a short circuit directly. In this very simple embodiment of my invention, a braking torque is produced by the starting winding when the synchronous speed, corresponding to the starting number of poles, is exceeded, provided the starting number of poles is higher than the working number of poles. In order to suppress this undesired torque, it is advisable to disconnect the starting winding immediately after the connection of the resistances, whereby this latter is connected in series with the operating winding. With the last operating step, the resistance is short circuited. A practical embodiment of such an operating connection is illustrated by the diagram of Figure 1, where I have provided means for introducing ohmic or inductive impedance in parallel with the starting winding during intermediate starting steps. It is well known that the starting winding will develop a braking torque when operating above the synchronous speed, that is, if, during starting, the number of poles is larger than during working. Then, when the motor has reached the working speed which is near synchronism with the working number of poles, this speed is greater than the synchronous speed of the starting number of poles. In order to eliminate this negative torque, the starting winding must be cut off during working condition and the impedance is included in the circuit during the intermediate step to prevent the current through the working winding being excessive at the instant the starting winding is first eliminated. The last step of starting cuts off this resistance, placing the motor in an operative condition.

In this figure, A represents the starting winding which is shown to be three phase, B is the working winding, also three phase, which is of different number of poles, and U is a three-pole switch which successively connects the contacts 1*a*, 1*b* and 1*c* connected respectively to the three phases of the starting winding, contacts 2*a*, 2*b* and 2*c* which are respectively connected to impedance elements *Za*, *Zb* and *Zc*, such as ohmic resistances, and finally, contacts 3*a*, 3*b* and 3*c*, which connect the three working windings into star connection.

During the first position of the switch, the starting winding is in series with the working winding, the motor starts and reaches near the synchronizing speed, corresponding to the number of poles of the starting winding. When the switch is placed on the second step, the impedances are connected in series with the working winding and by providing switch contacts C with sufficient width to span the two contacts 1*a* and 2*a* and the others respectively, it connects these impedances in parallel with the starting winding. With the further movement of the switch contacts, the starting winding is entirely disconnected and the impedance is connected in series with the working winding. Thus, the increase of current in the working winding is properly regulated. The third step of the switch connects a short circuit which places the working winding in star connection without any external impedance. During the second step, with the impedance in series with the working winding, the motor will tend to reach the synchronous speed of the working winding, thus on the third connection, an excessive rush of current is prevented. Thus the entire starting operation is carried out without any interruptions of the motor circuits.

The use of impedances Z may be dispensed with by providing means for changing the connection of the starting winding or of the operating winding or of both, for the purpose required in accordance with my invention, such as for instance, by carrying out a change from star connection to mixed connection to delta connection, such as is more particularly described in German Patent #416,662. Furthermore, the rotary fields, excited by the operating winding and by the starting winding respectively, may be controlled during the starting period in such a manner that with the first connecting step, the starting field is high and the operating field low, and that during the starting period, the starting field is weakened in more or fewer steps, whereas at the same time, the strength of the operating field is increased.

Figure 2 shows the different connections of the operating winding for the case that the change of connection is carried out in two intermediate steps for the operating winding (Figures 2*a*, 2*b*, 2*c*). At the first step, shown by Figure 2*a*, the operating winding B placed in series with the starting winding, is connected in star. At the first intermediate step shown by Figure 2*b*, the operating winding is arranged in a mixed connection and at the second intermediate step shown by Figure 2*c*, a delta connection of the operating winding is established. In the operating condition, the starting winding A is short circuited or disconnected. This disconnection of the starting winding may be carried out at the first intermediate

step and the short circuit operation of the starting winding may be furthermore carried out directly or across the resistance or impedance in accordance with the system of connection of Figure 1. The transition from a star into a delta connection may furthermore be carried out without interrupting the motor circuits, by carrying out the switching operations of the three phases successively instead of simultaneously.

For most practical purposes, one intermediate step will be sufficient. Thus, for instance, the motor may be started with the mixed connection of the operating winding B in accordance with Figure 2*b* and afterwards, the starting winding may be short circuited and the mixed connection of the operating winding substituted by the delta connection as shown by Figure 2*c*.

In case that it is desired to avoid the change of connections of the stator windings, in accordance with a further object of my invention, the starting winding may be short circuited in two or more steps, such as shown in Figure 3, where the starting winding is divided into two sections A1 and A2 to be short circuited in two successive steps.

B represents again the operating winding and A1 and A2, the two sections of the starting winding.

Referring to Figure 4, which combines both methods of Figures 2 and 3, this is particularly applicable to motors of large power. The working winding is connected in star during starting and in delta during working and a sectionalized starting winding is provided, the sections of which are gradually short circuited. In this figure, items A1 and A2 represent two sections of the starting winding, while items B1 and item B2 represent two sections of the working winding. The switch arms C1, C2, C3, C4, C5 and C6, which are shown as independent elements, are placed on a common shaft to be simultaneously operated or else with the contacts positioned as illustrated on the drawings, when the starting winding is first gradually cut out and the working winding is then gradually changed from star to delta connection. By such arrangement, it will be seen that during the starting step, the starting field will be strong, while the working field is weak. During the starting period, the starting field is gradually weakened and the working field gradually strengthened.

Referring especially to starting switches C4, C5 and C6, it will be seen that on position 1*a*, 1*b* and 1*c*, two sections of the starting winding are connected in series and are therefore in their most effective position. On the step 2*a*, 2*b* and 2*c*, one of the sections of the starting winding A1 is short circuited, thus reducing the effectiveness of the starting winding to one section A2, while increasing the total current which flows through the working windings B1 and B2 and thus increasing the effectiveness of the working field. On position 3*a*, 3*b* and 3*c*, the starting winding is completely short circuited and the working winding alone is connected into star connection. This position corresponds to position 3*a'*, 3*b'* and 3*c'* of the switch arms C1, C2 and C3 respectively. On the following steps, the starting winding remains short circuited, while the working winding goes through the following conditions:—

When the switch arms C1, C2 and C3 are on contacts 4*a*, 4*b* and 4*c*, the two sections of the working winding B1 and B2 in each phase, instead of being connected in star, are now in a mixed relation, so that sections B1 are still in a star connection, while the sections B2 are in a delta connection. This gives an increase in the current in the working winding and therefore tends to bring the motor into synchronism. On the final step of the starting switch 5*a*, 5*b* and 5*c*, the sections of the working winding B1 and B2 on each phase are connected in an ordinary delta connection and the motor is therefore in operating condition.

During one of the intermediate steps of the switch U, the section A1, in accordance with Figures 3 and 4 of the starting winding, is short circuited. By suitably sectionalizing the starting winding into sections A1 and A2, it is possible to suppress the rotary field of the starting winding during the short circuit of the section A1 so that only the magnetic leakage between both sections is effective, which constitutes a leakage impedance connected in series with the operating winding B. The operation of the motor is then essentially similar to that in accordance with Figure 1.

Figure 5 shows the connection of this sectionalized starting winding in a diagrammatic form, representing one phase only, wherein the circuit *a*0 to *a*1 corresponds to section A1 of Figure 2 and section *a*1 to *a*2 corresponds to section A2 of Figure 2. It will be seen when these two sections are connected in series, the currents in these two sections flow in the same direction as shown by the arrows in the figure, and therefore assist each other in producing a starting field. If, however, a short circuit is placed on the terminals *a*0 and *a*1, the current in section A1 is reversed, so that the rotary field is dampened and only the leakage inductivity between these sections is left. Both sections of the starting winding which need not necessarily have the same number of turns or coils, may be arranged in the same slots or they may be arranged in different slots, depending on whether a small or a large inductivity of the starting winding during the intermediate step is desired. If it is desired to further increase this in-

ductivity connected in series with the operating winding, this may be readily accomplished by small magnetic auxiliary circuits, such as illustrated by M in Figures 6*a* and 6*b*. With both sections of the starting winding connected in series as referred to in Figure 6*a*, the currents linked with the magnetic circuit M are cancelling each other in their resultant effect, whereas with one of the sections short circuited, their actions are added such as may readily be seen from Figure 6*b*. The direction of the current flow in Figures 6*a* and 6*b* is indicated by arrows. The magnetic circuits M may consist of thin sheets of iron placed around the outside connecting slots of the windings.

The same object may be obtained by arranging such magnetic circuits in the slots as shown by Figures 7 and 8. In these figures, the winding sections A1 and A2 of the starting winding are arranged at the bottom of the slot and the operating winding occupies the remaining upper space.

Referring to Figure 6, the loop illustrated as A1 corresponds to one section of the starting winding; the loop represented by A2 as the other section. In this figure, these loops represent the actual coils which are dropped in the slots of the motor with the ends of the coil projecting outside of the slots. A magnetic loop M which may consist of iron wire or other suitable material encircles these ends of coils as illustrated in this figure. Referring to the left side of Figure 6*a*, a direction of current is illustrated corresponding to the first starting condition where the currents in the two sections have the same direction. With the arrangement of magnetic loop M as illustrated, these currents cancel in their effect, on the magnetic loop and they can therefore flow freely through the circuits. On the right-hand of this figure, under 6*b*, the directions of current are illustrated, corresponding to the second and subsequent starting positions and to the working condition of the motor, whereby through transformer action, opposite currents flow in the two sections. It will now be seen that the magnetic loop M is subjected to magnetization by currents flowing in each of the windings A1 and A2 and therefore exercises a maximum impedance effect on these windings.

Figure 7 shows the two sections A1 and A2 located at the bottom of a slot of the motor and magnetic shunts "*s*" located between these two sections. This can be readily understood to correspond in its action to that of the loop M of Figure 4.

Figure 8 shows the two sections A1 and A2 located in two different slots and again the magnetic shunts "*s*" correspond in their action to that of loop M. As the operating winding in both cases is arranged at the upper side of the slots towards the opening, the power factor of the motor will not be deleteriously affected to a practical extent during operation, by the iron sheets "*s*".

Having fully described the object and the manner of operation of my invention in its preferred embodiments, to which however, I am not limited, but which may be changed in accordance with the specific structure of the motor and its connections, what I believe to be new and desire to secure and protect by Letters Patent of United States, is:

1. In an alternating current motor with starting and working windings of different number of poles a source of power supply, both of said windings being connected to said source at starting, a switch, connections from this switch to said working and starting windings, successive contacts on said switch and connections from said contacts to said starting windings, and means including said connections for reducing the effectiveness of said starting winding, and simultaneously increasing the effectiveness of said working winding during operation of said switch.

2. In an alternating current motor having a starting winding and a working winding of different number of poles connected in series at starting, a switch with successive contact points, connections from said switch to said working winding, connections from said switch to said starting winding, sections in said starting winding in series, connections from said sections to said switch, and means including said connections for gradually short circuiting the sections of this starting winding.

3. An arrangement as in claim 2, sections in said working winding, connections from said sections to said switch arranged so that said sections are changed gradually from a star connection to a delta connection.

4. An arrangement as in claim 2, said sections of the starting winding being arranged so as to have one of said sections when short circuited oppose the magnetic field produced by the other of said sections.

5. In an alternating current motor with starting winding and working winding of different number of poles, a switch with contacts, connections from said switch to the starting winding and working winding, sections in said starting winding, connections from said sections to said switch, all of said connections arranged to short circuit successively the sections of said starting winding by movement of said switch and means associated with said starting winding sections to increase the leakage inductance between said windings.

6. An arrangement as in claim 5, wherein said means include a magnetic loop encircling said sections of the starting winding.

7. An arrangement as in claim 5 wherein said means comprise magnetic shunts located

between the sections of said starting winding and form a magnetic loop around them.

8. In an alternating current motor having a starting winding and a working winding of different number of poles, a power supply source, said starting winding and said working winding being connected to said source at starting, a switch with successive contacts, connections from said contacts to said starting winding and said working winding, and means including said connections for reducing the effectiveness of said starting winding while simultaneously increasing the effectiveness of said working winding during operation of said switch.

9. In an alternating current motor having a starting winding and a working winding of different number of poles, a power supply source, said starting winding and said working winding being both connected to said source at starting, a switch with successive contacts, sections in said working winding, connections from said sections to said switch, sections in said starting winding, further connections from said sections of said starting winding to contacts of said switch, and means including said connections for reducing the effectiveness of said starting winding while simultaneously increasing the effectiveness of said working winding during operation of said switch.

10. In an alternating current motor having a starting winding and a working winding of different number of poles both windings being connected in series at starting, a switch with successive contacts, sections of said working winding, connections from said switch to said sections, sections in said starting winding in series, further connections from said last sections to said switch, and means including said connections for successively short circuiting the sections of said starting windings and for changing the sections of said working winding from a star to a mixed to a delta connection during the operation of said switch from its "off" to its "on" position.

11. In an alternating current motor having a starting winding and a working winding of different number of poles, a power supply source both of said windings being connected to said source at starting, a switch with successive contacts, sections of said working winding, connections from said sections to said switch, said starting winding consisting of two sections in series at starting, connections from said last mentioned sections of said starting winding to said switch, and means including said connections for successively short circuiting the sections of said starting winding and for changing said sections of said working windings successively from a star to a mixed to a delta connection during the operation of said switch from its "off" to its "on" position, and means whereby one of said sections of said starting winding being short-circuited opposes the magnetic field produced by the remaining section of said working winding.

12. In an arrangement as claimed in claim 11 whereby further means are provided to increase the leakage inductance between said sections of said starting winding.

13. In an arrangement as claimed in claim 11 in which there are provided magnetic loops encircling said sections of said starting winding.

14. In an arrangement as claimed in claim 11 in which there are arranged magnetic shunts located between said sections of said starting windings and form a magnetic loop around the same.

In testimony whereof I affix my signature.

RUDOLF RICHTER.