Nov. 14, 1939. A. LYSHOLM 2,179,556

METHOD OF MAKING TURBINES

Filed Feb. 13, 1937 2 Sheets-Sheet 1

Fig. 1

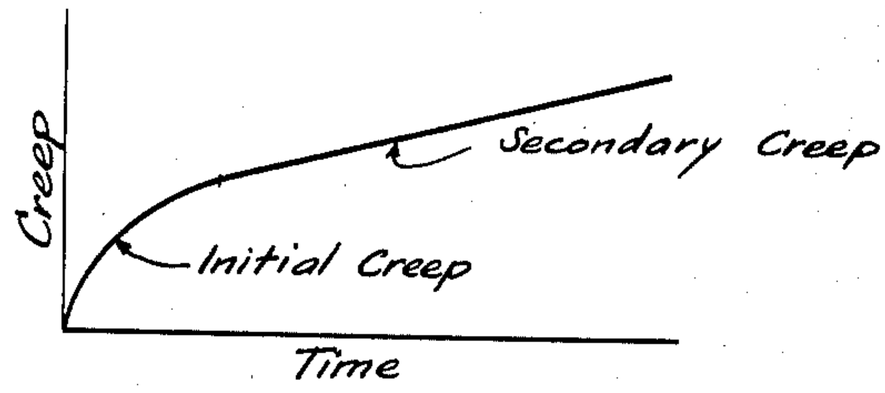
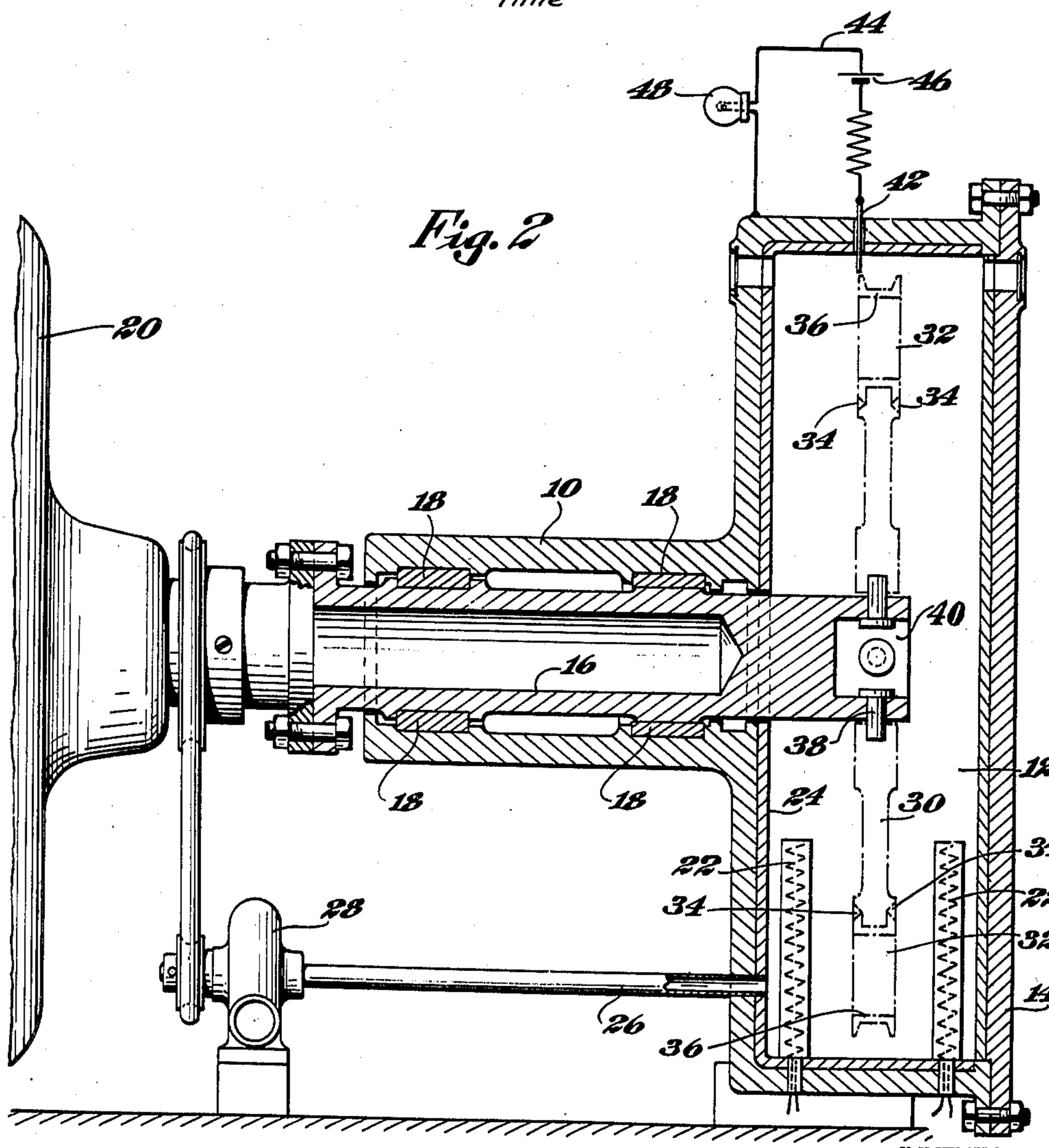


Fig. 2



INVENTOR.
A. Lysholm

BY
Jarvis C. Marble
his ATTORNEY.

Nov. 14, 1939. A. LYSHOLM 2,179,556

METHOD OF MAKING TURBINES

Filed Feb. 13, 1937 2 Sheets-Sheet 2

Fig. 3

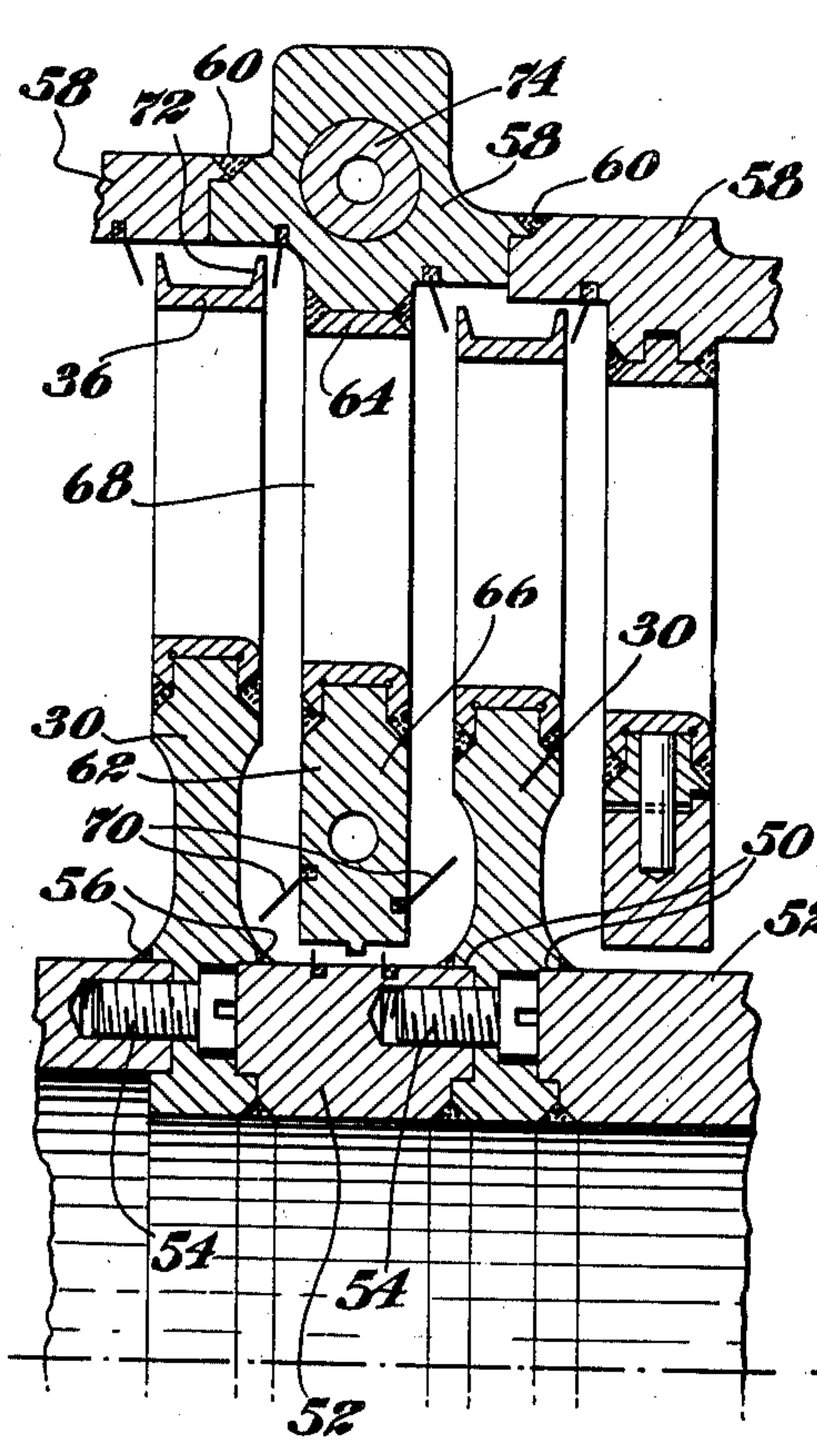


Fig. 4

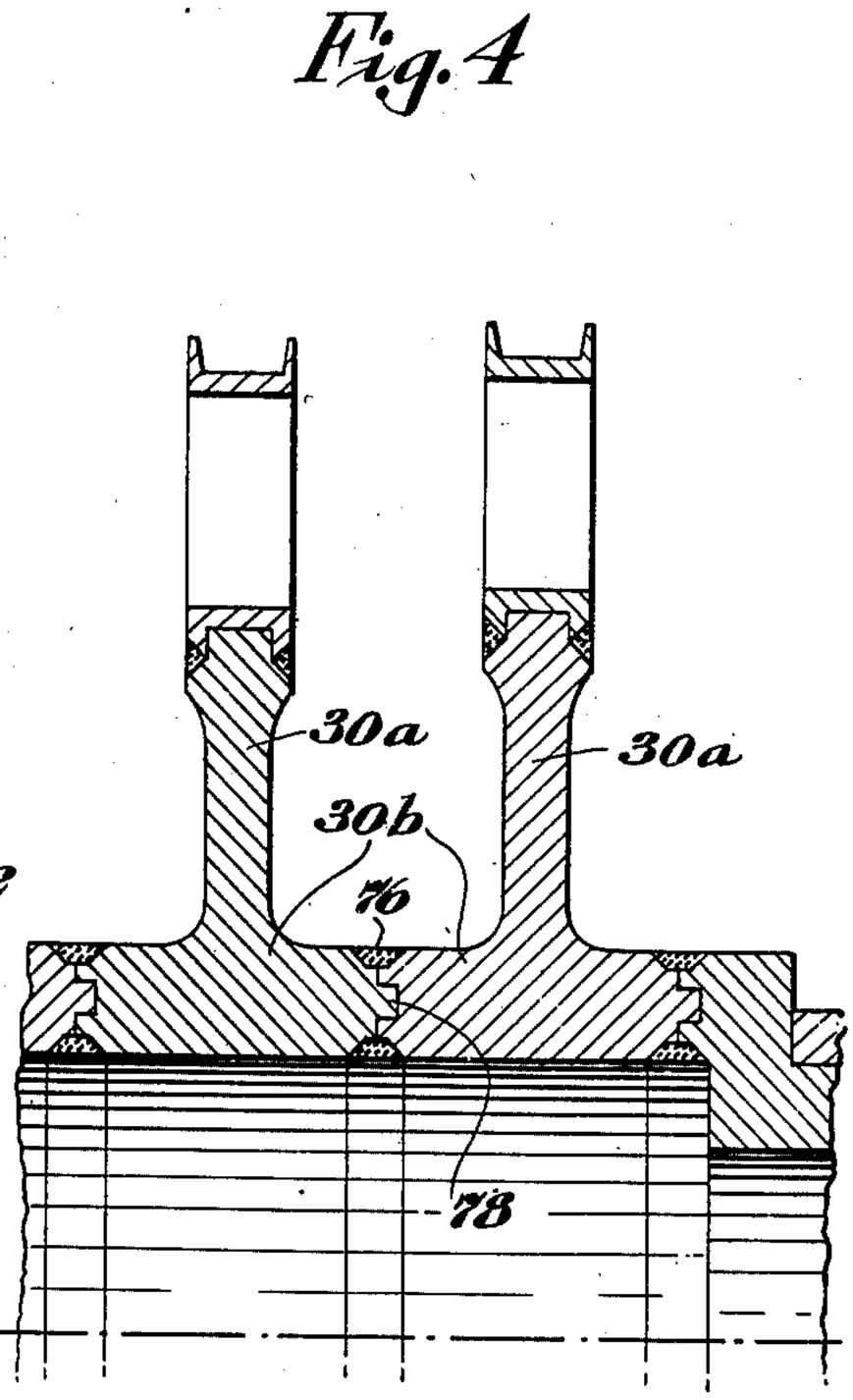
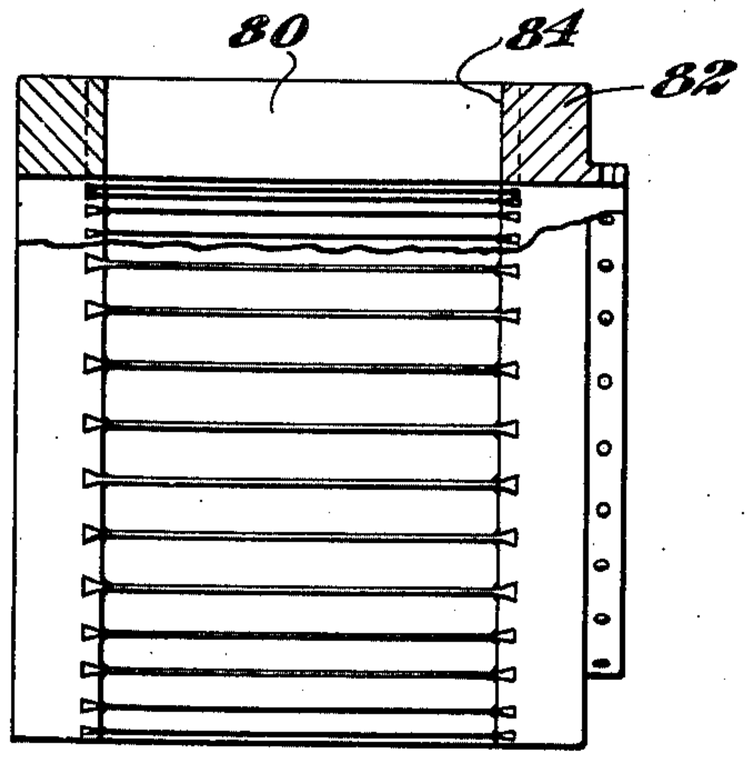


Fig. 5



INVENTOR.
A. Lysholm
Daniel C. Mabie
his ATTORNEY.

BY

Patented Nov. 14, 1939

2,179,556

UNITED STATES PATENT OFFICE

2,179,556

METHOD OF MAKING TURBINES

Alf Lysholm, Stockholm, Sweden, assignor to Aktiebolaget Milo, Stockholm, Sweden, a corporation of Sweden

Application February 13, 1937, Serial No. 125,647
In Great Britain March 8, 1933

10 Claims. (Cl. 29—156.8)

This application is a continuation in part with respect to my copending application Serial No. 713,904, filed March 3, 1934, and as to common subject matter, relates back to said application Serial No. 713,904.

The present invention relates to turbines adapted to operate with motive fluid at high temperature and has particular reference to the manufacture of and material for turbine parts subjected to severe temperature and/or mechanical stress conditions during normal operation of the turbine. Still more particularly the invention relates to manufacture of and material for turbine rotor parts, particularly the rotor blading and the rotor parts for carrying the same.

When steels of the kind usually used for turbine blading and rotor structure are continuously and concomitantly subjected to high temperature and high mechanical stresses, they are subject to a physical change in the form of a permanent growth which is different from the enlargement resulting merely from the temporary expansion of the metal under the influence of heat alone. This permanent growth is known as creep, and while the amount of increase in volume of the metal due to the creep is relatively small compared to the total volume of the metal, it is sufficient to alter the dimensions of the parts within a turbine, and particularly the clearances, when it occurs in the metal of the turbine structure.

A fundamental characteristic of this phenomenon of creep is that it is not uniform with respect to time. Assuming the metal to be subjected to creep producing conditions, the creep is initially at a comparatively rapid rate, and as the length of time of service of the metal under the creep producing conditions continues, the rate of creep diminishes because of the so-called hardening strains set up in the metal after it has been in service for a considerable period of time under such conditions. Thus, creep may be said to be divisible into initial creep which occurs at a relatively rapid rate and secondary creep, which occurs at relatively much slower rate.

As will be readily understood by those skilled in the turbine art, permanent enlargement of rotor parts due to creep may adversely affect many of the clearances within the turbine so that such clearances are larger than is desirable. Certain other clearances may be reduced by growth of parts due to creep. In either case the creep adversely affects the performance of the turbine. Thus, if in a particular instance creep operates to cause an enlargement of a clearance, the rate of creep causes such enlargement to occur after the turbine has been in service for a comparatively short proportion of its useful life and thereafter the turbine must operate with a considerably larger than desirable clearance at such place. This cannot be avoided by making the parts oversize to begin with since the desirable maximum clearances are so small that the parts would be in contact and would bind if initially made so as to compensate for the increase in clearance which would be produced by the subsequent creep. In the case of a reduction in clearance due to creep, the necessary initial allowance for the clearance spaces to avoid subsequent contact of the parts after the creep had taken place and reduced the clearance spaces would require initial clearances too great to be efficient, which clearances would remain too great for a substantial time of operation. As noted above, creep is gradual and it is also relatively slow. In some instances, many hundreds or even thousands of hours of operation may be required to effect the total or substantially total amount of creep that will be produced in the metal owing to the stresses of operation in the turbine.

In built-up turbine rotor structures, creep is productive of other undesirable conditions as well as change in clearances. One such condition is the loosening of parts due to the change in dimensions thereof. It has previously been suggested to avoid this latter difficulty by welding together of the assembled parts, and so-called "seasoning" of rotors has been resorted to in some instances in the belief that local over stressing of material, which is relieved by such seasoning, and which may be occasioned by welding or other strains occasioned by the assembling, are responsible for the difficulties encountered with turbine structures exposed to creep producing conditions. Loosening of parts of assembled rotors, which may be attributed to creep, may be avoided by making assemblies, such as blades and blade carriers, integral, but such construction is extremely expensive as compared with built up structures. Moreover, integral construction does not avoid the difficulties occasioned by the adverse effect of creep upon the clearance spaces in the turbine.

In accordance with the present invention, I propose to substantially reduce and for all practical purposes eliminate the difficulties heretofore encountered because of creep in turbine parts by producing creep in the parts subjected to creep producing conditions, prior to the final finishing and assembly of such parts in the turbine.

Owing to the great length of time necessary to produce all of the creep that may occur, it is not

ordinarily practical to attempt to produce all such creep prior to final manufacture but owing to the large proportion of the total creep that is occasioned by the comparatively rapidly occuring initial creep, such creep may practically and advantageously be produced in the desired parts before assembly thereof in the turbine. By producing such initial creep in the metal prior to finishing the turbine, the parts may be finished to provide desirably close initial clearances and the remaining creep which will occur during the normal life of the turbine, being secondary creep of relatively very low rate and relatively small magnitude, will not seriously interfere with the operation or efficiency of the turbine when these factors are considered in the light of the total life of the turbine.

In order to produce the initial creep, I propose to subject the parts in which it is desired to produce such creep to temperature and mechanical stresses substantially in excess of the like stresses to which the parts are subjected in actual service, for a period sufficient to cause such initial creep to take place. While under normal service conditions the initial creep might require hundreds of hours of operation to take place, such creep can be produced within a number of hours sufficiently small to make the treatment economically practical when the parts are subjected to substantial over stresses, since the rate of creep, and particularly the rate of initial creep, increases with increase in the value of either temperature stress or mechanical stress.

Stated in another way, I propose to produce initial creep in the metal at an artificially accelerated rate by subjecting the metal which in service will be subject to creep producing conditions, to exaggerated values of such conditions, whereby the usually very long time element involved in developing creep may be reduced to a comparatively very short time for the initial creep, which constitutes that part of the creep which, if not compensated for, is productive of the greatest difficulties in subsequent turbine operation.

While the total amount of creep and the rate at which creep occurs are both subject to variation because of different temperature and mechanical stress conditions, and also will vary with different specific materials, I have found that for purposes of practical utility, the objects of the present invention may be attained by following certain general rules, the variations in which will readily be appreciated by those skilled in the art when consideration is given to the following, given by way of example but without limitation.

Depending upon the character of use to which a given part or parts is to be put, the treatment to produce creep is preferably carried out to a degree such that the amount of creep produced causes enlargement of the dimensions by an amount in the range of from 0.5% to 1.0%, and in any event the increase in dimension produced should be not less than 0.1%.

In the table below there is given typical examples of advantageous treatment for representative carbon and alloy steels of the kind commonly employed for various turbine parts for high temperature turbines.

Turbine parts	Intended normal operating conditions				Stresses for creep treatment		
	Material	Stress	Temp.	Time	Stress	Temp.	Time
		Tons/sq. in.	*°F.*	*Hours*	*Tons/sq. in.*	*°F.*	*Hours*
Turbine disc and blades	Austenitic chrome nickel tungsten alloy containing 18% chrome, 8% nickel and 2-4% tungsten.	5	1,200	10,000	10	1,350	30-50
Turbine casing	Mild carbon steel containing 0.3% carbon	2.0	750	30,000	8	900	30-50
Do	Martensitic chrome nickel molybdenum alloy containing 0.8% chrome, 3% nickel and 0.5-1% molybdenum.	4	850	30,000	12	1,000	30-50

From the above table it will be evident that in order to secure the results which I wish to obtain, I prefer to reduce the time element required by increasing the amount of mechanical over-stress as compared with the normal operating stress more than the amount of excess temperature applied. One of the important reasons for doing this is that because of the critical temperatures of the material, heating to extremely high values during the treatment may so reduce the tensile strength of the material as to preclude applying thereto the high values of mechanical stress that are desired.

It will be observed from the above table that time, and a very considerable time, is required even under the severe conditions of over-stress, in order to cause the initial creep to be effected which is necessary to make the treatment effective for the purposes desired in the subsequent operation of the turbine. In this respect the process is very different from the so-called seasoning and other like processes heretofore applied to turbine and other mechanical parts for the purpose of relieving local stresses and strains produced by the fabrication of the parts.

For purposes of explaining more in detail the manner in which the invention may advantageously be carried into effect, reference may be had to the accompanying drawings forming a part of this specification and the description thereof which follows:

In the drawings:

Fig. 1 is a diagram showing the general nature of the primary and secondary creep which occurs in metals.

Fig. 2 is a diagrammatic view partly in section illustrating an apparatus for effecting the proposed creep producing treatment.

Fig. 3 is a fragmentary section showing a portion of an axial flow turbine rotor and casing structure made in accordance with the invention.

Fig. 4 is a similar view of another form of axial flow turbine rotor construction.

Fig. 5 is a view showing a rotor blade ring for a radial flow turbine.

In carrying the invention into effect the parts in which creep is to be produced may be subjected to heat and mechanical stress by various different kinds of apparatus, but the nature of the parts to be treated is usually such that the mechanical stress is advantageously applied by subjecting the parts to the centrifugal force developed by high rotative speeds. By way of example, but without limitation, I have illustrated in Fig. 2, in diagrammatic form, one form of apparatus suitable for the purpose.

Referring to Fig. 2, the apparatus comprises a suitably mounted stationary casing 10 providing a heating chamber 12, access to which is afforded by the removable cover plate 14. A shaft 16, mounted in bearings 18, extends at one of its ends into chamber 12. This shaft is adapted to be driven at high speed by a suitable turbine or motor, such as is indicated at 20.

Any suitable means may be employed for heating the interior of chamber 12 to high temperature. Hot steam, gas or air may be passed through the chamber, but for reasons which will be explained, electric heating units, such as indicated at 22, may advantageously be employed. In order to increase the heating efficiency the walls of the chamber may advantageously be heat insulated as at 24.

When the chamber is heated electrically or by application of heat from an external heating chamber (in which latter event the insulation 24 would be dispensed with) it is advantageously connected as by a conduit 26 to a vacuum pump 28, which may be driven by the motor 20, the pump serving to evacuate air or gas from the chamber.

The end of shaft 16 which extends into chamber 12 may be equipped with any suitable means for attachment thereto of the part or parts to be treated. By way of example I have shown mounted for treatment a turbine blade carrier having welded thereto at its circumference, by means of welds 34, a ring of turbine blades 32. The blades 32 are surrounded by the outer shroud ring 36. Carrier 30 is conveniently mounted by means of a number of radial pins 38 extending into suitable recesses in the carrier and removable through the socket 40 to release the carrier.

The blade carrier 30, which may be one of the elements for forming a built-up turbine rotor of the kind shown in Fig. 4, is advantageously manufactured to semi-finished dimensions, the blades 32 welded thereto and the assembly heat treated to remove welding strains before being placed in the treating chamber.

In the treating chamber the carrier is then rotated under excess temperature conditions of the order given in the table previously set forth and at a speed which will over-stress the parts, due to centrifugal force, to the desired degree. During the period of treatment the chamber 12 is preferably evacuated by the vacuum pump so as to minimize windage losses and consequently reduce the amount of power required for the operation.

The treatment is continued for the length of time required to produce the percentage of increase in dimension of the parts desired for the particular parts being treated. Such increase in dimension may very readily be measured, either optically or electrically and by way of illustration I have shown an electrical device consisting of a contact electrode 42 adjustably mounted in the casing 10 in any convenient manner and insulated therefrom, which electrode forms one terminal of an open electric circuit 44 energized by a current source such as a battery 46 and including a signal such as a buzzer or lamp 48 which is energized when the circuit is closed. Casing 10 forms a part of the circuit and the circuit is closed when contact is made between the electrode 42 and the periphery of the part being treated, in this instance the shroud ring 36. It will be evident with an arrangement such as this the electrode 42 can initially be set so that closing of the circuit will be effected only after the diameter of the part being treated has increased, due to creep, by the predetermined amount.

After the desired amount of creep has been produced, the treated part is allowed to cool and is then finished to final dimensions. For the purposes of this specification and the claims appended hereto, the term "finishing to final dimensions" is employed in the sense of defining that step or those steps of machining by cutting, broaching, grinding, or the like required to bring the parts so finished to desired final dimensional size as, for example, that specified on shop drawings, independent of additional operations such as straightening or the removal or addition of localized bodies of metal possibly required to balance a rotating part which has been finished to final dimensions. It will be evident that prior to treatment it will be necessary to leave unfinished only those dimensions which involve the fitting of the part to other parts and/or which involve the determination of the clearance spaces within the turbine.

Referring now to Fig. 3, the construction illustrated shows carrier discs of the kind shown in Fig. 2, the rotor assembly being formed by carriers 30, the hub portions of which are recessed as at 50 to receive spacer rings 52. The spacer rings and the carriers are advantageously bolted together as by means of bolts 54 which serve to hold the assembly together while it is welded as at 56. At the ends of the hollow rotor shaft formed by the hub portions of the carriers and the intermediate spacer rings, end pieces providing journals for the rotor are secured in known manner, the general form of built-up rotor structure being of known character.

It will be evident that in order to carry out the object of the present invention it is not necessary in all instances to separately treat each blade carrier. In axial flow turbines the diameters of the blade carriers ordinarily increase from the inlet to the outlet end by small increments and the turbine may in many instances include groups of carriers of the same diameter. Adjacent carriers of like or substantially like diameter are subjected in service to substantially like temperature and mechanical stress conditions and such groups of parts may conveniently be treated simultaneously to produce the initial creep in the parts. Thus, for example, two carriers with their intermediate spacing ring 52 may be treated as a unit, but in this connection it is to be noted that in such treatment the parts should be of balanced construction so that the mechanical stresses will be evenly distributed. For example, an assembly consisting of one carrier 30 and one ring 52 should not be treated together since if this were done the ring 52 would not be evenly stressed, the extending or free end of the ring being subjected to less stretching force than the end attached to the disc, since the larger diameter of the disc will cause greater stresses to be induced therein than in the ring, with a consequent tendency of the disc to stretch more than the ring and stretch the attached end of the ring more than the free end.

It is advantageous to treat the turbine casing as well as the turbine rotor parts, particularly when the turbine is intended to be used for extremely high motive fluid temperatures, such as those which are reached in gas turbines. To this end the construction of the turbine casing is advantageously of the form indicated in Fig. 3 in which it is made up of a number of sections 58

welded together at 60 and having welded thereto the stationary diaphragms 62 comprising outer and inner rings 64 and 66 respectively, between which are secured the stationary turbine blades 68.

Leakage past the various blade rings is reduced by the usual packing strips 70 illustrated more or less diagrammatically in Fig. 3, some of these strips being carried by the rotor structure and some by the stationary structure. The ribs 72 at the outer circumference of the shroud rings 36 may also function as radially disposed packing means.

The casing rings 58 may be advantageously parted along a central plane, the turbine casing being formed in two-halves held together by means of suitable bolts 74.

By making the casing ring parts of ring-like form it is readily possible to subject these parts to the creep producing treatment which provides further insurance against undesirable alteration of the clearance spaces during the life of the turbine.

Fig. 4 illustrates another form of axial flow rotor construction in which the blade carriers 30*a* are provided with laterally extending hub portions 30*b*, which hub portions take the place of the spacer rings 52 in the form of construction shown in Fig. 3. These hub portions are directly welded together as at 76 and are advantageously provided with centering flanges 78. The nature of the treatment to be given these carriers will be obvious from the previously described form.

In the manufacture of radial flow turbines, the blade systems of which are composed of a series of blade rings of the kind shown in Fig. 5, in which the blades 80 are welded at their ends to annular ring bonds 82, I prefer to first fix the blades 80 at their ends as by dovetailing and welding in known manner as at 84 to the ring bonds and then subject the assembled blade ring to the creep producing treatment. When annular parts of this character are treated, it will be evident that they may be secured for rotation to the shaft of a device such as shown in Fig. 2, by means of any suitable form of spider or carrier.

It will be evident that within the scope of the invention many variations of the specific mode of manufacture may be employed for different types of turbines. Different specific methods of forming and assembling the various parts may be employed which will occur to those skilled in the art, and likewise various specific modes of procedure which may be employed to produce the desired mechanical stress in the parts while maintaining them at high temperature will suggest themselves.

The invention is therefore not to be construed as limited to the specific examples hereinbefore given by way of illustration only but is to be construed to embrace all such variations in procedure as may fall within the scope of the appended claims when they are construed as broadly as is consistent with the state of the prior art.

What I claim is:

1. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which consists in producing in such member at least a substantial portion of the initial creep which would occur in the member in its intended use, and thereafter finishing the member to required final dimensions.

2. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which consists in subjecting the member to creep producing conditions of greater severity than those to which it would be subjected in its intended service, continuing such treatment until the rate at which creep occurs appreciably diminishes due to hardening strains resulting from the treatment, and thereafter finishing the treated part to required final dimensions.

3. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which consists in concomitantly subjecting the member to mechanical stress substantially greater than the normal operating stress in the turbine and to a temperature above the normal operating temperature in the turbine, continuing such treatment until at least a substantial portion of the initial creep of the metal has been produced and thereafter finishing the member to required final dimensions.

4. The method of manufacturing built up metal turbine structures intended to be operated under creep producing conditions in a turbine which includes the steps of welding semi-finished parts together, heat treating the welded-together parts to remove internal stress in the metal resulting from the welding, producing a predetermined amount of creep in the assembly of welded-together parts by subjecting the assembly to predetermined values of temperature and mechanical stress in excess of those to which the parts are subjected in normal operation, and thereafter finishing the parts to final dimensions.

5. The method of manufacturing metal turbine rotor parts comprising turbine blades and blade carriers intended for use under normal operating conditions of temperature and mechanical stress productive of creep in the metal of such parts which includes the steps of welding the blades to the carriers, heat treating the welded-together parts to remove internal stresses therein resulting from the welding, subjecting the welded-together parts to values of temperature and mechanical stress in excess of those to be encountered in the intended normal operation to produce a predetermined amount of diametrical enlargement of the parts due to creep and thereafter finishing the parts to final dimensions.

6. That improvement in the manufacture of built-up turbine rotors for use under normal operating conditions of temperature and mechanical stress productive of creep in the metal of the rotor which includes the steps of rotating component parts of the rotor at speeds sufficiently higher than their normal operating speed to produce therein stresses substantially higher than those encountered in normal operation, maintaining such parts at temperatures in excess of those encountered in normal operation while they are subjected to the excess stresses produced by such rotation, continuing such rotation until a predetermined measured diametrical enlargement of the parts due to creep is effected, finishing the component parts so treated to final dimensions, and assembling the parts so finished in the rotor.

7. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which consists in subjecting the member for a minimum period of the order of thirty hours to creep producing conditions of substantially greater severity than those to which it would be subjected in its intended service, and thereafter finishing the member to its required final dimensions.

8. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which consists in subjecting the member for a minimum period of the order of thirty hours to mechanical stress of at least the order of twice the mechanical stress to which it would be subjected in its intended service while maintaining the member at a temperature above that at which it would operate in its intended service, and thereafter finishing the member to its required final dimensions.

9. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which includes subjecting the member to creep producing conditions of substantially greater severity than those to which it would be subjected in its intended service, continuing such treatment until a dimensional increase of at least 0.1% in the size of the member is attained due to creep, and thereafter finishing the member to final dimensions.

10. That improvement in the manufacture of a metal member intended for use under creep producing conditions in a turbine which includes subjecting the member to creep producing conditions of substantially greater severity than those to which it would be subjected in its intended service, continuing such treatment until an increase in dimensional size of the member of the order of from 0.5% to 1.0% is attained due to creep, and thereafter finishing the member to required final dimensions.

ALF. LYSHOLM.