Method and apparatus for remote, individual control of separate coolant flow through control valves (112) to spray nozzles (102-106) lying along and about a continuous metal casting path to permit a nearly infinite variation in cooling patterns, which may be adjusted along and/or about the metal casting path as the casting metal advances. Remote individual spray nozzles coolant flow in continuous casting is safer and enables production of an improved product.
| AT  | Austria       | KR  | Republic of Korea         |
| AU  | Australia     | LI  | Liechtenstein             |
| BE  | Belgium       | LK  | Sri Lanka                 |
| BG  | Bulgaria      | LU  | Luxembourg                |
| BR  | Brazil        | MC  | Monaco                    |
| CF  | Central African Republic | MG  | Madagascar                |
| CG  | Congo         | MR  | Mauritania                |
| CH  | Switzerland   | MW  | Malawi                    |
| CM  | Cameroon      | NL  | Netherlands               |
| DE  | Germany, Federal Republic of | NO  | Norway                    |
| DK  | Denmark       | RO  | Romania                   |
| FI  | Finland       | SD  | Sudan                     |
| FR  | France        | SE  | Sweden                    |
| GA  | Gabon         | SN  | Senegal                   |
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INDIVIDUALLY CONTROLLED SPRAY NOZZLE SYSTEM
AND METHOD OF USE FOR CASTER

TECHNICAL FIELD

This invention relates to apparatus for casting of molten materials and especially casting molten metals. It is more particularly concerned with continuous casting machines.

BACKGROUND ART

Efficient and effective cooling, and control of that cooling have been major problems in continuous casting since the beginning of the technology.

Although recent advances in the art of cooling continuously cast metal bar are a significant improvement over previous cooling methods, such methods still do not necessarily achieve complete uniformity. Thus the problems of inverse segregation, center liquation and porosity still may adversely affect the subsequent working characteristics of the cast metal bar.

A desirable property of almost any metal alloys, preferably in its as-cast condition, is a uniform distribution within the cast product of the constituents and impurities normally found in the alloy. As used herein, what applicant believes to be the meaning of these terms is the ordinary meaning in the art. That is, "constituent" means one of the intended ingredients or elements which make up a metallurgical system or a phase or combination of phases which occur in a characteristic configuration in an alloy microstructure. "Impurities" means elements or compounds whose presence in any material is unintended and generally undesired. Constituents, as used herein, then, would include the materials combined into a metallurgical system to produce the particular type of alloy being cast but would not include the impurities, or undesired elements or compounds present in the cast metal. In any case,
segregation of the components in the cast alloy makes it less suitable for subsequent processing such as forging or rolling. As used herein, the term "segregation" also has what applicant believes to be its normal meaning in the art. That is, segregation is a term used to describe the non-uniform distribution or concentration of constituents (and/or impurities) which arises during the solidification of a metal.

For example, a concentration or accumulation of impurities in various positions within a metal is referred to in the art as segregation. The segregation that occurs between the arms of dendrites is referred to as minor or microsegregation and thus the composition may vary within a single crystal. Macrosegregation occurs around primary or secondary shrinkage cavities, such as pipe and in similar regions, and is often revealed in some castings as marked lines, having a pronounced erect or inverted cone shape, which are made evident when the ingots are sectioned and etched. Zones of segregation tend to occur in but are not limited to, the middle regions of the casting and usually within that part mainly occupied by equiaxed crystals. Microsegregation may sometimes be overcome by annealing, but macrosegregation often persists through subsequent heating and working operations. So-called pipe segregates may occur around the pipe cavity. In normal segregation, in steel alloys, for example, the constituents (solute) in the iron (solvent) rejected from the freezing liquid are known to accumulate at the advancing solid/liquid interface so that the constituents of lowest melting point concentrate in the last portions to solidify. In inverse segregation however, for example in aluminum alloys, this is reversed, for the liquid with high solute concentration becomes trapped in between the dendrites, thereby causing a decrease in concentration of solutes from the surface toward the center. Inverse segregation, then, is a concentration of constituents or impurities to a higher degree near the outer
surfaces (as compared to the interior) of an ingot or casting.

Prior art methods of casting alloys have provided cast products having a relatively high degree of segregation of impurities and alloying materials within the cast bar. Because of the high level of constituents and impurities in many aluminum and steel alloys, inverse segregation frequently occurs. Such uneven distribution of impurities and/or constituents within the cast bar makes it desirable that the total amount of such within the alloy be reduced so that subsequent processing of the cast bar does not result in unacceptable internal and surface characteristics in the product manufactured from the cast bar. A reduction in the total amount of impurities, however, usually requires expensive additional refining of the alloy prior to casting and is sometimes commercially unfeasible or impractical altogether, while on the other hand the addition of particular constituents (including alloying elements) is sometimes desirable or necessary.

Among the impurities and alloying elements within steel likely to become segregated in prior art casting processes are sulphur, oxygen, phosphorus, manganese, silicon and carbon. Any significant segregation of such will make the steel less commercially useful. For example, significant segregation may cause non-uniformity of tensile strength within a particular piece of steel and make it less suitable for subsequent drawing into wire. Segregation of gaseous impurities may result in areas of porosity near the top surface of the cast product, which, among other drawbacks, causes inferior sheet surface quality.

Finished products such as wire and cable produced from aluminum alloy bar cast with prior art non-uniform cooling methods have lower electrical conductivity, strength, and ductility qualities than those produced by the present invention.
Wheel-band casting machines have been commercially available for non-ferrous metals since about 1950; numerous attempts to control the cooling of the mold have been made over the years, notably illustrated by U.S. patents number 2,379,000 ("the '000' patent"), 3,318,369 ("the '369' patent"), 3,319,700 ("the '700' patent"), 3,329,197 ("the '197' patent"), 3,454,077 ("the '077' patent"), and 3,623,535 ("the '535' patent") and its related 3,774,669 ("the '669' patent) apparatus patent.

As progressive companies expanded the continuous casting technology from lower molten temperature metals to higher molten temperature metals, the need for fast, effective and uniform cooling of the casting mold and its contents became ever increasingly more important in obtaining a marketable, defect-free product. A major advance was made with the '000 patent, which development was essential to economical conversion of the process from aluminum to copper metals. The great advantage of this patent was that it enabled adjustment of the coolant flow against the inner periphery of the casting mold to accommodate the thermal dynamics of a solidifying metal within a moving mold. To facilitate this, a multiplicity of carefully located and positioned angled spray nozzles were directed to apply coolant against the mold in a desired pattern. Some degree of remote adjustment was provided by dividing the sprays into groups and supplying Water to a central, partitioned manifold. Each supply pipe from the manifold to the sprays was controllable, as was the collective supply from a main, remotely controllable source. This technological step enabled continuous casting of copper and its alloys in such a casting machine.

The '369 patent was an attempt to provide even greater uniformity of casting wheel cooling to the moving casting mold, though it was necessarily more complex, and subject to clogging of the cooling passages when using unsophisticated and unclean water sources for cooling water.
A further improvement, the '700 patent attempted to localize the water sources from which water was applied to the casting mold by providing radially extending channels to control the water flow. It was later discovered that increased water flow velocity in certain casting mold configuration cooling channels improved cooling uniformity; see the '197 patent. The foregoing methods, however, required massive use of water coolant; to avoid the excessive use of cooling water, the '077 patent was developed in which the coolant was supplied through a concentric channel shaft, reducing the number of liquid-tight water seals and reducing coolant loss. Wheel mold replacement was also facilitated.

With the advent of the '535 and '779 patents, however, internal spray cooling was again used successfully, in combination with direct secondary spray cooling of the still unsolidified bar exiting from the caster. As described in these patents (and in the 000 patent), maximum cooling effectiveness within the mold varies along the length of the mold. Thus, removing the casting from the mold after a solidified shell has formed but before the core solidifies, followed by direct application of coolant enables maximally effective cooling.

Another type of prior art apparatus and method, disclosed in U.S. Patent 3,346,038, uses independently adjustable jets in corresponding inner and belt-side sections of the casting machine mold. Although this system recognizes the need for individualized control, it fails to achieve uniform cooling because it neglects two sides of the mold by controlled cooling of only the inner and belt sides, and because it has no temperature or flow monitoring system.

Various methods have heretofore been tried in ensuring maximally efficient and effective cooling of castings, but direct access to individual spray adjustments is hazardous when possible, and usually not practical for lack of access. Zone cooling, as based in the '000 patent has therefore been
the preferred method of operating cooling adjustment prior to the present invention. Yet, years of operating experience with various metals and alloys indicates a need for the ability to carefully and precisely adjust both the cooling of the mold and of the metal, if secondary cooling is used, at all points along the casting path until solidification is effected.

It is now known that with certain casting machines, such as those wherein at least one of the mold surfaces is variable in length by adjusting the length of a band material closing the mold, that cooling conditions may require great change. In particular, U.S. Patent Number 3,996,993 to Bonnamour discloses a wheel-band casting machine wherein the length of band covering the peripheral groove in the casting wheel is changed in length as casting and cooling conditions permit. There is presently no method or apparatus by which the cooling can be smoothly, uniformly and effectively changed as the solidifying metal progresses along the casting path to avoid a defective section of cast bar when the mold length is changed. Nor is there presently known a means of varying the cooling slightly along and about the casting path so as to accommodate variable mold lengths, as may be required when varying such casting parameters as casting speed, metal temperature, etc. These casting parameters also vary with the metal and alloy being cast, requiring variations in cooling objectives which are difficult to maximize as to uniformity and effectiveness.

DISCLOSURE OF INVENTION

In the continuous casting of metals along a predetermined casting path, it is necessary to control the application of coolant to at least one of either the mold or the solidifying metal, or both. Various methods have been tested and used commercially, both with short mold casting apparatus and with longer mold path casting apparatus, and with variable mold lengths.
The improvement of the present invention in cooling uniformity and effectiveness is achieved by incorporating remotely variable individual spray nozzle adjustment and control method and apparatus such that extremely precise cooling control is achievable about and along the casting path, even though various casting conditions may become present during a cast. The nozzle changes are shown effected, by way of example but not limitation, by means of pneumatic controls. Changes may similarly be effected by electrically driven valves, which may also be remotely and individually adjusted. Any known pressure means, including hydraulic pressure, may be used. With pneumatic controls, failure of the pneumatic system may cause loss of control over coolant flow from the individual nozzles and collectively, over the entire system. This could be a catastrophic event when casting certain metals which react explosively to contact with water by forming superheated steam extremely rapidly.

Nevertheless, for simplicity, a hydraulically controlled, individually variable cooling nozzle control system in combination with a wheel-bend casting machine is disclosed for simplicity of understanding. It is contemplated that other remotely controlled sprays and other continuous casting apparatus may fall within the purview of the present invention as claimed. Specifically, the Spraytec "Selectospray" system of differential cooling headers is described in modified form, as is required to adapt same to the present invention. Among other modifications the Spraytec nozzle controls must be adapted to a circular manifold to fit within the casting wheel and spray water against the inner and outer walls of the casting wheel. By careful selection of the spacing of the individual remotely controlled nozzles on these manifolds, an extremely large number of individually cooled and controlled segments of the casting mold can be utilized along the casting path.

It is therefore an object of this invention to provide means and method for adjusting the flow of coolant along the
casting path for optimum uniform cooling of the molten metal.

Another object of this invention is to provide means for the remote adjustment of cooling applied to the cast metal along the casting path.

Yet another object of this invention is to accommodate the need to precisely and accurately vary the application of coolant, by remote means, at a multiplicity of segmented locations along and peripherally about the longitudinal path of travel of the casting.

Still another important object of this invention is the provision of method and apparatus to smoothly, uniformly, and effectively change the cooling conditions along and about the casting path to accommodate variations in the casting conditions or parameters.

And yet another important object of this invention is the provision of method and apparatus to vary the cooling conditions transverse to the casting path such that cast strip could be cooled differently across the width of the strip.

Still another object of this invention is the provision of method and apparatus for localized detection and remote signaling of cooling conditions along the casting path, so as to enable continuous control of cooling parameters.

BRIEF DESCRIPTION OF DRAWINGS

Numerous other features and advantages of the invention disclosed herein will be apparent upon examination of the several drawing figures forming a part hereof, and in which like reference characters indicate corresponding parts in all views:

FIG. 1 is a side elevation view of a typical wheel-band continuous casting apparatus incorporating the cooling means of the present invention,

FIG. 2 is a side elevation view of the wheel-band casting machine of FIG. 1,
FIG. 3 is a view of a typical spray manifold, and
FIG. 4 is a sectional view of one form of remotely adjustable spray nozzle suitable for incorporation in the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Now in order to implement these and still further objects of the present invention, which will become more readily apparent as the description proceeds, the apparatus aspects of this development are manifested by the following features illustrated in the drawings forming a part hereof.

Figure 1 illustrates one typical system for continuously casting and forming a molten metal. The molten metal to be cast is supplied by a melting or holding furnace 1 in which the chemical composition and temperature of the metal are adjusted as necessary. The molten metal is then introduced in a continuous manner into the moving mold portion of the casting apparatus 20, which mold is formed by a thin metallic band covering a portion of a peripheral groove in a rotatable casting wheel. Coolant is applied to the mold surfaces to functionally extract the heat from the molten metal at a rapid rate to both solidify the metal and to prevent the mold surfaces from overheating.

After solidification the cast metal bar is extracted from the casting apparatus 20 and typically guided through a shearing station 30, which may be used to sever sections of the cast bar if required during the initial starting up of the system, and through a bar preparation station 40 which may clean or condition the bar for rolling. A rolling mill 50 works the cast metal bar into rod by a plurality of roll stands which each reduce the bar cross section while elongating it into wrought rod.

From the rolling mill 50 the wrought rod is guided through a cleaning and/or cooling section 60 and thence to a coiler station 70 where the finished rod is collected into coils for convenient handling, storage, or shipment.
Referring now in more detail to FIG. 2, one type of casting apparatus 20 for the continuous casting of metal is shown with some parts eliminated for clarity but which is generally well known in the art. Casting machine 20 includes a rotatable casting wheel 211, an endless flexible metallic band 212, and band positioning rollers 214a, 214b, 214c, 214d which position and guide the band 212 about a portion of the casting wheel 211.

The casting wheel 211 is removably affixed to rotatable support plate 215 which in turn is adapted to be driven by a variable-speed motor (not shown) so as to rotate the wheel assembly in a clockwise direction. The casting wheel 211 has an outwardly facing annular peripheral groove which is closed by band 212 to form an arcuate mold cavity which extends about the lower portion of casting wheel 211.

The first band positioning roller 214a, which is hereinafter called the presser wheel, functions to position or press the band 212 against the casting wheel 211 so as to tightly seal this portion of the peripheral groove which is to receive the molten metal.

The last band positioning roller 214d, which is hereinafter called the tension wheel, is usually movable in a vertical direction and functions to tension band 212 against the lower portion of the casting wheel 211.

There are usually two or more other band positioning rollers 214b and 214c which are often called idler wheels and which function merely to guide the band 212 along its path from the tension wheel 214d back to the presser wheel 214a.

During use, the band 212 sealingly engages the casting wheel 211 so that as casting wheel 211 is rotated by support plate 215, the band 212 is urged along its path at the same speed. Thus a moving mold cavity is formed within the lower portion of the casting wheel.
Molten metal is supplied to the moving mold cavity from a furnace through a pouring pot 225 and pouring spout 224. The rate of flow of molten metal from the pouring spout 224 is regulated by suitable means so that the level of the molten metal pool within the casting mold remains just below the point at which the presser wheel 214a seals the band 212 against the peripheral groove in the casting wheel 211.

As casting wheel 211 is rotated, the molten metal is carried along its arcuate path within the moving mold where it is solidified by the cooling system and subsequently extracted as a cast bar for further processing.

The cooling system comprises a multitude of liquid spraying nozzles which direct a coolant, such as water, against the surfaces of the casting wheel 211 and the band 212 so as to extract heat therefrom thus also extracting heat from the metal within the moving mold.

Cooling of the mold is accomplished with a plurality of cooling manifolds disposed along and about the continuous casting path. A large inner manifold 249 as configured in FIG. 2 shows a multiplicity of individual spray nozzles 230 for directing coolant (not shown) against the inner periphery of the casting wheel 211. Coolant is supplied to manifold 249 via coolant supply pipes 262 and 263.

A series of external coolant manifolds are normally disposed alongside the casting path outside of the mold. Such manifolds may each be of single chamber or multiple chamber design, as desired. In FIG. 2, the band spray apparatus is comprised of multiple manifolds 240, 241, and 242, although a single manifold may also be used. Coolant is supplied to the manifolds through supply pipes 237, 238, and 239. Manifolds are also used to supply coolant to a multiplicity of sprays (not shown) for the sides of the casting mold; FIG. 2 shows two side manifolds 245, 246 on the exposed side; the manifolds on the other side are hidden from view. Again, a single manifold may be used. In this example, coolant from pipe 263 is supplied to the manifolds.
via pipes 247, 248. Occasionally it is found desirable to include other spray manifolds at various positions about and/or along the casting or band path, which manifolds are not shown in these drawings. The methods indicated are discussed above and may be applied as described above. All of the manifolds may be curved as required.

Turning now to FIG. 3, there is shown a portion of an interior wheel spray manifold adapted for use according to the present invention, including manifold coolant supply pipe 100, manifold 101, and a series of individual remotely controllable valve and spray cooling nozzles means 102, 103, 104, 105, and 106. One valve and nozzle means 106 is shown in partial cutaway view to enable observation of the general coolant flow path therethrough. FIG. 4 shows the coolant flow through the nozzle means more clearly. In FIG. 3, a coolant supply pipe 100 provides coolant under fluid pressure from a remote source means (not shown) to manifold 101, which in turn feeds each nozzle 102, 103, 104, 105, 106 means. A series of pneumatic valve control lines 107, 108, 109, 110, and 111 regulate the position of a valve, within the spray nozzle base, which valve is remotely controlled and regulated by controlling the fluid pressure on each valve as is more particularly described in association with FIG. 4. The nozzle means (102, 103, 104, 105, and 106) each comprises a valve (not shown) within a valve containing body 112, a control line 109, an internal coolant path 113, a preferably angularly offset nozzle base 114, and the nozzle per se, 115. Various spray patterns can be chosen from in selecting nozzles 115 having different spray deflection surfaces, such as are well known in the art. It should be noted here that the spray valve remote control lines 107, 108, 109, 110 and 111 only generically represent control lines in FIG. 3. That is, the control line may consist of a sealed pneumatic tubing in the case where the spray nozzle control valve is pneumatically controlled, or of one or more electrical conductors where the spray valves are
electrically controlled. The present disclosure is not intended to be limiting to a particular control method or mechanism, but is rather directed at the more general concept of individual remote control.

Turning now to FIG. 4 there is shown a more detailed view of the inner workings of one form of spray nozzle control valve. The body of the valve is fixed to the coolant manifold 101 in which coolant 120 is supplied under pressure via pipe 100. The valve body 112 includes therewithin a coolant passageway extending along the path from inflow orifice communicating passageway 113a to exit orifice communicating passageway 113b, along the path between which lies a flow control valve means including gate 122 and seat 121. Valve stem 123 extends into pneumatic cylinder 127 where a piston 124, sealingly engaged with the cylinder walls, is attached to valve stem 123. A stepped peripheral extension from valve stem 123 functions as a stop 125 for a spring 126 positioned between cylinder end cover 129. Spring 126 may be either an expansion spring (so as to close off coolant flow) or a retraction spring (so as to increase coolant flow) as desired. Pneumatic pressure changes within the cylinder, effected by pressure changes applied via pneumatic control orifice 128, cause the pneumatic piston to open or close the valve, controlling coolant flow. The pneumatic pressure is communicated via tubing to remote control apparatus, which may be monitored by pressure/vacuum measuring devices to indicate coolant valve settings; the pressure/vacuum measuring devices may be calibrated in relation to coolant flow to remotely indicate coolant flow.

Alternatively, the coolant flow may be remotely controlled by an electrical current applied to a small, high torque reversible motor connected to an externally threaded valve stem moving within a fixed threaded element, thereby opening or closing the valve or restricting the flow as desired.
As may readily seen from the foregoing, it is possible to vary the cooling conditions along and about the casting mold axis at discrete time intervals corresponding to the passage of molten metal through the casting mold. In this manner, it is possible to smoothly, uniformly, and effectively change the cooling conditions along and about the casting path to accommodate variations in the casting conditions or parameters, such as casting rate. Therefore, the nonuniform character of the cast metal, resulting from segregation, inverse segregation, liquation, and center porosity which results from non-uniform cooling (which may be caused by non-uniform casting rate or other casting parameters) can be avoided with the present invention.
I CLAIM:

1. Improved apparatus for continuous casting of molten metals including mold means for containing said molten metal along a continuously moving mold path, means for cooling said molten metal within said mold means by application of coolant sprays, the improvement comprising a plurality of individual valve means for regulation of the flow of coolant through corresponding individual coolant spray nozzle means, each valve means including adjustment means responsive to control means, said valve means and said coolant spray nozzle means being in close proximity to said mold path.

2. Improved apparatus for continuous casting of molten metals as in Claim 1 and further comprising: a first discrete plurality of individual valve means for regulation of the flow of coolant through corresponding individual coolant spray nozzle means which direct coolant against a portion of the mold surface along the longitudinal axis of the mold, and successive discrete pluralities of such individual valve means and coolant spray nozzle means disposed along successive portions of the mold path's longitudinal axis.

3. Improved apparatus for continuous casting of molten metals as in Claim 1 and further comprising: a first discrete plurality of individual valve means for regulation of the flow of coolant through corresponding individual coolant spray nozzle means which direct coolant against a portion of the mold surface along the mold longitudinal axis and about a limited portion of the radius about the mold longitudinal axis, and successive discrete pluralities of such individual valve means and coolant spray nozzle means disposed radially about successive portions of the mold longitudinal axis portions.
4. Apparatus as in Claim 1 further characterized in that the valve adjustment means are individually responsive to pneumatic control means.

5. Apparatus as in Claim 4 further including pneumatic conduit means and remote pneumatic control means, said pneumatic conduit means communicating with said valve means and said remote pneumatic control means.

6. Apparatus as in Claim 1 further characterized in that the valve adjustment means are individually responsive to electrical control means.

7. Apparatus as in Claim 6 further including electrical current-carrying means and remote electrical control means, said electrical current-carrying means connected between said valve means and said remote electrical control means.

8. In a process of the type wherein molten metal is poured into a continuous casting mold cavity, cooled to at least partial solidification by a plurality of individual coolant spray nozzles located along the longitudinal axis of the mold, and extracted from the mold in a substantially continuous length, the improvement comprising: the steps of individually controlling the flow of coolant to the spray nozzles by remotely controlled adjustment of valves associated with each spray nozzle.

9. The method of Claim 8 further characterized in that adjustment of the separate valves is accomplished by varying an electrical control signal.

10. The method of Claim 8 further characterized in that adjustment of the separate valves is accomplished by varying a pneumatic control pressure.
11. The method of Claim 8 further including the steps of varying the rate at which molten metal is poured into the continuous casting mold, varying the rate of extraction of the at least partially solidified metal, and adjusting the coolant flow through the valves associated with each spray nozzle such that the molten metal is uniformly cooled about and along the longitudinal axis of the mold as the metal advances through the mold.
I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

Int Cl 3 B22D 11/06, 11/124
US Cl 164/414, 433

II. FIELDS SEARCHED

<table>
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<th>Classification System</th>
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<tr>
<td>U.S.</td>
<td>164/414, 433, 434, 443, 455, 482</td>
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Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to Claim No.</th>
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<tr>
<td>Y</td>
<td>GB A 1,441,273 Published 30 June 1976</td>
<td>1-11</td>
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<td>Y</td>
<td>US A 3,626,479 Published 7 December 1971</td>
<td>1-11</td>
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<tr>
<td>A</td>
<td>US A 3,417,810 Published 24 December 1968</td>
<td>1-11</td>
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<td>A</td>
<td>US A 3,478,808 Published 18 November 1969</td>
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* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
- "Y" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "Z" document member of the same patent family

IV. CERTIFICATION

Date of Completion of the International Search: 6 February 1984

Date of Mailing of this International Search Report: 15 FEB 1984

International Searching Authority: ISA/US

Signature of Authorized Officer: KUANG Y. LIN

EXAMINER: GROUP 320