INVENTION.*

By Hon. CHARLES A. PARSONS, M.A., F.R.S., M.I.C.E.

ON this occasion I propose to devote my remarks to the subject of invention.

It is a subject of considerable importance, not only to engineers but also to men of science and the public generally.

I also propose to treat invention in its wider sense, and to include under the word discoveries in physics, mechanics, chemistry, and geology.

Invention throughout the middle ages was held in little esteem. In most dictionaries it receives scant reference except as applied to poetry, painting, and sculpture.

Shakespeare and Dryden describe invention as a kind of muse or inspiration in relation to the arts, and when taken in its general sense to be associated with deceit, as, "Return with an invention, and clap upon you two or three plausible lies."

As to the opposition and hostility to scientific research, discovery, and mechanical invention in the past, and until comparatively recent times, there can be no question, in some cases the opposition actually amounting to persecution and cruelty.

The change in public opinion has been gradual. The great inventions of the last century in science and the arts have resulted in a large increase of knowledge and the powers of man to harness the forces of nature. These great inventions have proved without question that the inventors in the past have, in the widest sense, been among the greatest benefactors of the human race. Yet the lot of the inventor until recent years has been exceptionally trying, and even in our time I scarcely think that anyone would venture to describe it as altogether a happy one. The hostility and opposition which the inventor suffered in the middle ages have certainly been removed, but he still labors under serious disability in many respects under law as compared with other sections of the community. The change of public feeling in favor of discovery and invention has progressed with rapidity during the last century. Not only have private individuals devoted more time and money to the work, but societies, institutions, colleges, municipalities, and governments, have founded many research laboratories, and in some instances have provided large endowments. These measures have increased the number of persons trained to scientific methods, and also provided greatly improved facilities for research; but perhaps one of the most important results to engineers has been the direct and indirect influence of the more general application of scientific methods to engineering.

Sir Frederick Bramwell, in his presidential address to this Association in 1888, emphasized the interdependence of the man of science and the civil engineer, and described how the work of the latter has been largely based on the discoveries of the former, while the work of the engineer often provides data and adds a stimulus to the researches of the man of science. And I think his remarks might be further appropriately extended by adding that since the man of science, the engineer, the chemist, the metallurgist, the geologist, all seek to unravel and to compass the secrets of nature, they are all to a great extent interdependent on each other.

But though research laboratories are the chief centers of scientific invention, and colleges, institutions, and schools train the mind to scientific methods of attack, yet in mechanical, civil, and electrical engineering the chief work of practical investigation has been carried on by individual engineers, or by firms, syndicates, and companies. These not only have adapted discoveries made by men of science to commercial uses, but also in many instances have themselves made such discoveries or inventions.

To return to the subject, let us for a moment consider in what invention really consists, and let us dismiss from our minds the very common conception which is given in dictionaries and encyclopædias that invention is a happy thought occurring to an inventive mind. Such a conception would give us an entirely erroneous idea of the formation of the great steps in advance in science and engineering that have been made during the last century; and, further, it would lead us to forget the fact that almost all important inventions have been the result of long training and laborious research and long-continued labor. Generally, what is usually called an invention is the work of many individuals, each one adding something to the work of his predecessors, each one suggesting something to overcome some difficulty, trying many things, testing them when possible, rejecting the failures, retaining the best, and by a process of gradual selection arriving at the most perfect method of accomplishing the end in view.

This is the usual process by which inventions are made.

Then after the invention, which we will suppose is the successful attempt to unravel some secret of nature, or some mechanical or other problem, there follows in many cases the perfecting of the invention for general use, the realization of the advance or its introduction commercially; this after-work often involves as great difficulties and requires for its accomplishment as great a measure of skill as the invention itself, of which it may be considered in many cases as forming a part.

If the invention, as is often the case, competes with or is intended to supersede some older method, then there is a struggle for existence between the two.

This state of things has been well described by Mr. Fletcher Moulton. The new invention, like a young sapling in a dense forest, struggles to grow up to maturity, but the dense shade of the older and higher trees robs it of the necessary light. If it could only once grow as tall as the rest all would be easy, it would then get its fair share of light and sunshine. Thus it often occurs in the history of inventions that the surroundings are not favorable when the first attack is made, and that subsequently it is repeated by different persons, and finally in different circumstances it may eventually succeed and become established.

We may take in illustration almost any of the great inventions of undoubted utility of which we happen to have the full history—for instance, some of the great scientific discoveries, or some of the great mechanical inventions, such as the steam engine, the gas engine, the steamship, the locomotive, the motor car, or some of the great chemical or metallurgical discoveries. Are not most, if not all, of these the result of the long-continued labor of many persons, and has not the financial side been, in most cases, a very important factor in securing success?

The history of the steam engine might be selected, but I prefer on this occasion to take the internal-combustion engine, for two reasons—first, because its history is a typical one; and secondly, because we are to hear a paper by that able exponent and great inventor in the domain of the gas engine, Mr. Dugald Clerk, describing not only the history, but the engine in its present state of development and perfection, an engine which is able to convert the greatest percentage of heat units in the fuel into mechanical work, excepting only, as far as we at present know, the voltaic battery and living organisms.

The first true internal-combustion engine was undoubtedly the cannon, and the use in it of combustible powder for giving energy to the shot is strictly analogous to the use of the explosive mixture of gas or oil and air as at present in use in all internal-combustion engines; thus the first internal-combustion engine depended on the combination of a chemical discovery and a mechanical invention, the invention of gunpowder and the invention of the cannon.

In 1680 Huygens proposed to use gunpowder for obtaining motive power in an engine. Papin, in 1690, continued Huygens's experiments, but without success. These two inventors, instead of following the method of burning the powder under pressure, as in the cannon, adopted, in ignorance of the thermodynamic laws, an erroneous course. They exploded a small quantity of gunpowder in a large vessel with escape valves, which after the explosion caused a partial vacuum to remain in the vessel. This partial vacuum was then used to actuate a piston or engine and perform useful work. Subsequently several other inventors worked on the same lines, but all of these failed on account of two causes which now are very evident to us. First, gunpowder was then, as it still is, a very expensive form of fuel, in proportion to the energy liberated on explosion; secondly, the method of burning the powder to cause a vacuum involves the waste of nearly the whole of the available energy, whereas had it been burned under pressure, as in the cannon, a comparatively large percentage of the energy would have been converted into useful work. But even with this alteration, and however perfect the engine had been, the cost of explosives would have debarred its coming into use, except for very special purposes.

We come a century later to the first real gas engine. Street, in 1794, proposed the use of vapor of turpentine in an engine on methods closely analogous to those successfully adopted in the Lenoir gas engine of eighty years later, or thirty years ago. But Street's engine failed from crude and faulty construction. Brown, in 1823, tried Huygens's vacuum method, using fuel to expand air instead of gunpowder, but he also failed, probably on account of the wastefulness of the method.

Wright, in 1833, made a really good gas engine, having many of the essential features of some of the gas engines of the present day, such as separate gas and water pumps, and water-jacketed cylinder and piston.

Barnett, in 1839, further improved on Wright's design, and made the greatest advance of any worker in gas engines. He added the fundamental improvements of compression of the explosive mixture before combustion, and he devised means of lighting the mixture under pressure, and his engine conformed closely to the present-day practice as regards fundamental details. No doubt Barnett's engine, so perfect in principle, deserved commercial success, but either his mechanical skill or his financial resources were inadequate to the task, and the character of the patents would seem to favor this conclusion, both as regards Barnett and other workers at this period. Up to 1850 the workers were few, but as time went on they gradually increased in numbers; attention had been attracted to the subject, and men with greater powers and resources appear to have taken the problem in hand. Among these numerous workers came Lenoir, in 1860, who, adopting the inferior type of non-compression engine, made it a commercial success by his superior mechanical skill and resources. Mr. Dugald Clerk tells us: "The proposals of Brown (1823), Wright (1833), Barnett (1838), Bunsanti and Matteucci (1857), show gradually increasing knowledge of detail and the difficulties to be overcome, all leading to the first practicable engine in 1866, the Lenoir." This stage of the development being reach-

ed, the names of Siemens, Beaudé, Roches, Otto Simon, Dugald Clerk, Priestman, Daimler, Dowson, Mond, and others, appear as inventors who have worked at and added something to perfect the internal-combustion engine and its fuel, and who have helped to bring it to its present state of perfection.

In the history of great mechanical inventions there is perhaps no better example of the interdependence of the engineer, the physicist, and the chemist than is evinced in the perfecting of the gas engine. The physicist and the chemist together determine the behavior of the gaseous fuel, basing their theory on data obtained from the experimental engines constructed by the mechanical engineer, who, guided by their theories, makes his designs and improvements; then, again, from the results of the improvements fresh data are collected and the theory further advanced, and so on until success is reached. But though I have spoken of the physicist, the chemist, and the engineer as separate persons, it more generally occurs that they are rolled into one, or at most two, individuals, and that it is indispensable that each worker should have some considerable knowledge of all the sciences involved to be able to act his part successfully.

Now let us ask, Could not this very valuable invention, the internal-combustion engine, have been introduced in a much shorter time by more favoring circumstances, by some more favorable arrangement of the patent laws, or by legislation to assist the worker attacking so difficult a problem? I think the answer is that a great deal might be done, and I will endeavor to indicate some changes and possible improvements.

The history of this invention brings before our minds two important considerations. First, let us consider the patentable matter involved in the invention of the gas engine, the utilization for motive-power purposes of the then well known properties of the explosive energy of gunpowder or of mixtures of gas and oil with air. Are not these obvious inferences to persons of a mechanical turn of mind and who had seen guns fired, or explosions in bottles containing spirits of turpentine when slightly heated and a light applied to the neck? Surely no fundamental patent could have been granted under the existing patent laws for so obvious an application of known forces. Consequently, patent protection was sought in comparative details, details in some cases essential to success which were evolved or invented in the process of working out the invention. In this extended field of operations a slight protection was in some instances obtained. But in answer to the question whether such protection was commensurate with the benefits received by the community at large, there can, I think, be only one reply. Generally, those who did most got nothing, some few received insufficient returns, and in very few cases indeed can the return be said to have been adequate. The second important consideration is that of the methods of procedure of the patentees, for it appears that very few of them had studied what had been suggested or done before by others before taking out their own patents. We are also struck by the number of really important advances that have been suggested and have failed to fructify, either from want of funds or other causes, to be forgotten for the time and to be re-invented later on by subsequent workers.

What a waste of time, expense, and disappointment would be avoided if we in England helped the patentee to find out easily what had been done previously; on the lines adopted by the United States and German patent offices, who advise the patentee after the receipt of his provisional specification of the chief anticipatory patents, dead or alive! And ought we in England to rest content to see our patentees awaiting the report of the United States and German patent offices on their foreign equivalent specifications before filing their English patent claims? Ought not our patent office to give more facilities and assistance to the patentee?

Before proceeding further to discuss some of the possible improvements for the encouragement and protection of research and invention, I ask you further to consider the position of the inventor—the man anxious to achieve success where others have hitherto failed. To be successful he must be something of an enthusiast; and usually he is a poor man, or a man of moderate means, and dependent on others for financial assistance. Generally, the problem to be attacked involves a considerable expenditure of money; some problems require a great expenditure before any return can thereby accrue, even in the most favorable circumstances. In the very few cases where the inventor has some means of his own they are generally insufficient to carry him through, and there have unfortunately been many who have lost everything in the attempt. In nearly all cases the inventor has to co-operate with capital; the capitalist may be a sleeping partner, or the capital may be held by a firm or syndicate, the inventor in such cases being a partner—a junior partner—or a member of the staff. The combination may be successful and lasting, but unfortunately the best inventors are often bad men of business. The elements of the combination are often unstable, and the disturbing forces are many and active; especially is this so when the problem to be attacked is one of difficulty, necessitating various and successive schemes involving considerable expenditure, generally many times greater than that foreshadowed at the commencement of the undertaking. In such circumstances, unless the capitalist or the senior partner or board be in entire sympathy

* Read before the British Association for the Advancement of Science.

with the inventor or exercise great forbearance, stimulated by the hope of ultimate success and adequate returns, the case becomes hopeless, disruption takes place, and the situation is abandoned. Further, in the majority of cases, after some substantial progress has been made, it is found that under the existing patent laws insufficient protection can be secured, and the prospect of a reasonable return for the expenditure becomes doubtful. In such circumstances the capitalist will generally refuse to proceed unless the prospect of being first in the field may tempt him to continue.

Very many inventors, as I have said, avoid the expense of searching the patent records to see how far their problem has been attacked by others. In some cases the cost of a thorough search is very great indeed; sometimes it is greater than the cost of a trial attack on the problem. In the case of young and inexperienced inventors there sometimes exists a disinclination to enter on an expensive search; they prefer to spend their money on the attack itself. There are some, it is true, who have a foolish aversion to take steps to ascertain if others have been before them, and who prefer to remain in ignorance and trust to chance. It will, however, be said that the United States and German patent office reports ought to suffice to warn or protect the English patentee; but my own experience has been that such protection is not entirely satisfactory. There is, first, a considerable interval before such reports are received, and the life of a patent is short. Then, if the patent is upon an important subject, attracting general attention, the search is vigorous and sometimes overwrought, and the patent unjustly damaged or refused altogether. If, however, the patent is on some subject not attracting general attention, it receives too little attention and is granted without comment.

In some few instances it may be said that ignorance has been a positive advantage, and that if the patentee had realized how much of his patentable work was honeycombed by previous publications and patents, he would have lost heart and given up the task. It is, I think, a case of the exception proving the rule; and the patentee ought, as far as possible, in all cases to know his true position, and make his choice accordingly. The present patent law has some curious anomalies. Let us suppose some inventor has the good fortune to place the keystone in the arch of an invention, to add some finishing touch which makes the whole invention a complete success, and valuable. Then, success having been proved possible, others try to reap the results of his labor and good fortune, and, as often happens, it is discovered after laborious search that some one else first suggested the same keystone in some long-forgotten patent or obscure publication, but for some reason or other the public were none the better for his having done so. What does the law do? It says this is an anticipation, and instead of apportioning to all parties reasonable and equitable shares in the perfected invention, to which no one could object, it says that the patent is injured or perhaps rendered useless by the anticipation, and that its value to everyone concerned is thereby diminished or destroyed, as the case may be, and thrown open to the public. Until a few years ago, any anticipations, however old, might be cited; but recently the law has been amended, and at present none rank as anticipations which are more than fifty years old.

The perfecting of inventions and their introduction into general use require capital, as we have seen—sometimes a considerable amount, as in the introduction of the Bessemer process for steel, or the linotype system of printing—before any commercial success can be realized.

Capital having been found, the next difficulty is in the conservatism of persons and communities who are the buyers of the invention. There is always present in their minds the risk of failure and its consequent loss and worry to themselves, and in the event of success the advantage, in their estimation, may not be sufficient to counterbalance the risk. In large departments and companies the management of which is conducted by officials receiving fixed salaries, acting under non-technical supervision, there is a strong tendency among the officials to leave well enough alone, the organization being such that the risk of failure, even though it be remote, more than counterbalances, in their estimation, the advantages that would result in the event of success. Next is the opposition of those who are financially interested in competing trades or older inventions; and if the invention is a labor-saving appliance, then the active opposition of the displaced labor is a serious, though generally only a temporary, barrier.

Fortunately, however, for the community, for research, and for invention, there is always to be found a considerable percentage of persons who, apart from the inventor, are able and willing to risk, and indeed to sacrifice, their personal interests in the cause of progress for the benefit of the community at large; and were it not for such persons the task of the introduction of most inventions would be an impossible one.

There are many problems of the highest importance in physics, engineering, chemistry, geology, and the arts, of which the investigation might probably prove of great benefit to the human race, and of which the probable monetary cost of the attack would be considerable, and of some very great indeed. Let us, then, inquire how the necessary funds could be raised. It is possible in the case of some of the more attractive problems that a group of rich philanthropists might

be found, but in most cases it would be impossible to form a company on business lines, under the existing laws of this and other countries, as I shall endeavor to show.

In the case of many of the problems, no patents will give adequate protection; in some cases there is no subject matter of novelty and importance involved. In other cases the probable duration of the investigation is so long that any initial patents would have expired before a commercial result was reached, and in either of these circumstances there would be no inducement to business men or financiers to undertake the risk.

As an illustration of my meaning I will take two investigations that have doubtless occurred to the minds of most of those present, though many others of greater or less importance might be cited. One is the thorough investigation of the problem of aerial navigation, with or without the assistance of flotation by gas. This problem could undoubtedly be successfully solved by an organized attack of skilled and properly trained engineers and the expenditure of a large sum of money. Assuming the problem solved, and commercially successful, it appears to be impossible under the existing patent laws to secure any adequate monopoly so as to justify the expectation of a reasonable return on the capital expended on the invention. For in view of the multitude of suggestions that have been made and the experiments that have been carried out, the practical solution of the problem would appear to rest on a judicious selection of old ideas by means of exhaustive experiments.

Another and perhaps more important investigation which has not, as yet, been attacked to any material extent is the exploration of the lower depths of the earth. At present the deepest shaft is, I believe, at the Cape, of a little more than one mile in depth, and the deepest bore-hole is one made in Silesia, by the Austrian government, of about the same depth. What would be found at greater depths is at present a matter for conjecture, founded on the dip and thicknesses of strata observed on or near the surface. Much money and many valuable lives have been devoted to exploration of the polar regions, but there can be no comparison between the scientific interest and the possible material results of such exploration and the one I have chosen for illustration of the inadequate protection afforded by law—namely, a great engineering attack on a problem of geology.

I would ask you to consider the commercial aspect of this engineering geological enterprise, as compared with exploration into new or unknown areas on the surface of the earth.

An exploring expedition into a new country has before it generally the probability of the acquisition of territorial and mineral rights or possessions bringing material gain to the undertakers. The rights of such enterprises are well known, and capital can be obtained with or without national support, as the case may be. On the other hand, the explorer into the depths of the earth has no rights or monopolies beyond the mineral rights of the land he has purchased over his boring; further, it is improbable that he can obtain any patent of substantial value for his methods of boring to great depths. To succeed in the undertaking a great expenditure of money must be incurred, an expenditure far greater than that of an exploring expedition, and analogous to that of a military expedition or a small invading army, and to raise this sum the pioneers have practically no security to offer. For if they succeed in finding rich deposits of precious minerals in greater abundance, or succeed in making some geological discovery associated with deep borings, they gain no exclusive title to these under existing laws. Any other person or syndicate acting upon the experience gained, could sink other shafts in other places or countries, and, benefiting by the experience gained by the pioneers, could probably carry out the work more advantageously, and thus depreciate the first undertaking or render it valueless, as has often occurred before.

Let us consider more closely some of the essential features of sinking a shaft to a great depth, for I think it will be seen that it presents no unsurmountable difficulties beyond those incidental to an enterprise of considerable magnitude involving the ordinary methods of procedure and the ordinary methods adopted by mining engineers. That there would be some departures from ordinary practice on account of the great depth is true, but these are more of the character of detail. On the design of this boring I have consulted Mr. John Bell Simpson, the eminent authority on mining in the north of England. The shaft would be sunk in a locality to avoid as far as possible water-bearing strata and the necessity of pumping. It would be of a size usual in ordinary mines or coal-pits. The exact position of such shaft would require some consideration as to whether it should commence in the primary or secondary strata. It would be sunk in stages, each of about half a mile in depth, and at each stage there would be placed the hauling and other machinery, to be worked electrically, for dealing with each stage. The depth of each stage would be restricted to half a mile in order to avoid a disproportionate cost in the hauling machinery and the weight of rope, as well as increased cost in the cooling arrangements arising from excessive hydraulic pressures. At each second or third mile in depth there would be air-locks to prevent the air-pressure from becoming excessive owing to the weight of the superincumbent air, which at from two to three miles would reach about double the atmospheric pres-

sure at the surface. A greater rise of pressure than this would be objectionable for two reasons—first, from the inconvenience of the workmen; secondly, from the rise of temperature due to the adiabatic compression of the circulating air for ventilating purposes. The air pressure immediately above each air-lock would thus reach to about two atmospheres, and beneath to one atmosphere. In order to carry on the transfer of air through the air-locks for ventilating purposes pumps coupled to air engines would be provided, the energy to work the pumps being obtained from electro-motors. To maintain the shaft at a reasonable temperature at the greater depth powerful means of carrying the heat to the surface would be provided.

The most suitable arrangement for cooling would probably consist of large steel pipes, an upcast and a downcast pipe, connected at the top and bottom of each half-mile section in a closed ring. This ring would be filled with brine, which by natural circulation would form a powerful carrier of heat; but the circulation, assisted by electrically-driven centrifugal pumps, would be capable of carrying an enormous quantity of heat upward to the surface. At each half-mile stage there would be a transfer of the heat from the ring below to the ring above by means of an apparatus similar in construction to a feed-water heater, or to a regenerator constructed of small steel tubes, through which the brine in the ring above would circulate, and around the outside the brine in the ring below could also circulate, the heat being transmitted through the metal of the tubes from brine ring to brine ring.

We have now presented to us two alternative arrangements for cooling. One arrangement would be to cool the brine to a very low temperature in the top ring at the mouth of the shaft by refrigerating machinery, so as to provide a sufficient gradation of temperature in the whole brine system, to insure the necessary flow of heat upward from brine ring to brine ring, and overcome all the resistances of heat-transfer, and so maintain the lowest ring at the temperature necessary for effectual cooling of the lowest section of the shaft. But a better arrangement would be to place powerful refrigerating machinery at certain of the lower stages, the function of this machinery being to extract heat from the ring below and deliver it to the ring above. This latter method would increase to a very great extent the heat-carrying power of the system, which in the first arrangement is limited by the freezing temperature of brine in the descending column and the highest temperature admissible in the ascending brine column. The amount of heat conducted inward through the rock-wall and requiring to be absorbed and transferred to the surface depends on the temperature and conductivity of the strata. But there is no doubt that the methods I have indicated would be capable of maintaining a moderate temperature in the shaft to a depth of twelve miles.

During the process of sinking at the greater depths the shaft bottom would require the application of a special cooling process in advance of the sinkers, similar to the Belgian freezing system of M. Poesche used for sinking through water-bearing strata and quicksands, and now in general use. It consists in driving a number of bore-holes in a circle outside the perimeter of the shaft to be sunk; through these bore-holes very cold brine is circulated, thus freezing the rocks and quicksands and the water therein, and when this process is completed the sinking of the shaft is easily accomplished.

In our case this process would be maintained not only on the shaft bottom, but also for some time on the newly-pierced shaft sides, until the surrounding rock has been cooled for some distance from the face.

As to the cost, rate of boring, and normal temperature of the rock, an approximate estimate has been made, based on the experience gained on the Rand, but including the extra costs for air-locks and cooling:

For	2 miles depth from the surface	Cost	Time in		Temp. of Rock
			Years	122 deg. F.	
" 4 "	" " " " " "	£ 500,000	10	122	" "
" 6 "	" " " " " "	1,100,000	25	152	" "
" 8 "	" " " " " "	1,800,000	40	182	" "
" 10 "	" " " " " "	2,700,000	55	212	" "
" 12 "	" " " " " "	3,700,000	70	242	" "
" 12 "	" " " " " "	5,000,000	85	272	" "

I hope I have succeeded in showing in the short time at our disposal that an exploration to great depths is not an impossible undertaking. But my main object in discussing the enterprise at some length has been to show that a pioneer company would not acquire any subsequent monopoly of similar works under the existing patent laws or the laws of any country.

In the scheme as I have described it, there appears to be nothing that could be patented; but let us suppose that some good patent could have been found that was absolutely essential to the success of the undertaking, it would certainly have expired before the pioneer company could have reaped any substantial return, and probably before the first enterprise had been completed. It follows therefore that at the present time there is no adequate protection, or indeed any protection at all, for the promoters of many great and important pioneer enterprises, some of which might prove of immense benefit to mankind.

Let us ask what change in the laws would place great pioneer research work on a sound financial basis. A government grant, except for very special purposes, seems to be out of the question, seeing that the benefits to be derived are generally not confined to any one country. An extension of the life of patents,

which is now from fourteen to sixteen years in different countries, would be undoubtedly a step in the right direction. It would be of great benefit generally if some scale of duration of patents could be fixed internationally, the scale being fixed according to the subject-matter, the difficulty of the attack, and the past history of the subject, but more especially in view of the utility of the invention.

One of the chief objections raised by the Privy Council against the extension of patents in this country has rightly been that undue prolongation is unfair to the British public, seeing that abroad no prolongations are granted. Therefore, if the duration of patents for important matters is to be extended at home it must also be extended abroad. In other words, such prolongations, to be effective, should necessarily extend to other countries. They should be international, and concurrent in all the countries interested.

One possible solution of this difficult question would be to place such matters under the jurisdiction of a central international committee, who would have the apportionment of the life and privileges of patents and of the extension or curtailment of their duration, according to their handling by the owners. I would ask, Why has a patent a life of only fourteen or sixteen years, while copyright is for forty-two years? Why has a pioneer company making a railway under act of Parliament generally rights forever unless it abuses its privileges, or the requirements of the district necessitate the construction of competing lines, while a patent has in comparison a life of infinite shortness?

I might also cite gas companies, electrical supply companies, under act of Parliament, or provisional orders of forty-two years' duration; and this reminds us of the fact that until the term of life for electric supply companies had been extended from twenty-one years to forty-two years by the bill of 1884, it was impossible to find capital for such undertakings.

Now, it may be urged that the grant of a patent is a different thing from the grant of power to a railway company, a gas or electric supply company. But the object of this address has been to show that a patent, to be fair to the patentee, ought in many cases to be analogous to an act of Parliament or a provisional order. Would it not place matters in a fairer position, especially in the case of expensive and lengthy researches, to grant to those who pledge themselves to spend a suitable and minimum sum within a stated period on the research a reasonable and fair monopoly, so that such person or syndicate might in the event of success be in the position to reap a reasonable return for their expenditure and risk?

Some such measure would unquestionably give an immense stimulus to research and invention by enabling capital to be raised and works started on commercial lines in fields of great promise at present almost untouched.

I pass over the disadvantages to the British inventor of the hostile patent tariffs of Continental nations and of the protective patent laws of some of the British dependencies, disadvantages greater than those imposed by protective tariffs on the ordinary British manufacturer.

There is, however, another aspect of the question to which I would briefly allude: it is the great benefits that the world at large has derived from the work of inventors in the past.

Think of the multitude and power of the great steam engines and gas engines that drive our factories, and pump the water out of our mines, and supply our cities with water, light, and power; of the great steamships scattered over the ocean and the locomotives on the railways.

Think of the billions of tons of steel that have been made by the Bessemer, Siemens-Martin, and Thomas Gilchrist processes, and of the great superiority and less cost of the material over the puddled iron which it superseded.

Think of the vast work performed by the electric telegraphs and telephones; and we must not fail to include the great chemical and metallurgical processes carried on all over the world, besides the countless other inventions and labor-saving appliances. Can we form any idea of the commercial value of all these gigantic tools that past inventors have left as a heritage to the human race, and can we venture to place any order of magnitude on so vast a sum?

If we take as our unit of value the whole of the money spent on all inventions, both successful and unsuccessful, I think we shall be much below the mark if we assume that the value of the benefits has on the average exceeded by ten-thousandfold the money spent on making and introducing the inventions.

If this is so, let us see what it means. It means that for every unit of capital spent by the inventors and their friends on invention they have in some cases received nothing back. In some cases they have just got their capital back, in some cases two or threefold, occasionally tenfold, very rarely a hundredfold. Whereas the world at large has received a present of ten-thousandfold greater value than all the money spent and misspent by the small band of past inventors.

In conclusion, let us hope that the inventor will in the future receive more encouragement and support, that the patent laws will be further modified and extended, that the people at large will consider these matters more closely and recognize that they are of first importance to their progress and welfare, and that in the future it may be easier, nay in some cases

possible, to carry on many great researches into the secrets of nature.

[Concluded from SUPPLEMENT No. 1503, page 24081.]

MODERN METHODS OF STEEL CASTING.*

By JOSEPH HORNER, A.M.I.Mech.E.

THOSE who are unfamiliar with foundry work may be surprised to learn that sand in cores and molds will interfere very greatly with the shrinkage of steel, and in a lesser degree with that of iron also. I have seen more than one large pipe, or cylinder, fractured in consequence of neglect to loosen the core in time; and

FIG. 16.—A BRICKED-UP LOAM MOLD (WITH COPE REMOVED) TO ILLUSTRATE RESISTANCE TO SHRINKAGE.

flanges torn off long pipes, due to resistance of the sand behind them. Fig. 16 represents a cylinder, or a large inlet pipe made in loam by bricking up. If this were cast in steel or iron, and left to cool without any precautions being taken, it would fracture across its diameter, A, and also between its flanges, B. This is prevented by laying, between the hard bricks, three or four courses of bricks made of dried loam, from top to bottom of the central core; and two or three horizontal courses of the same, around the top at a, underneath the flange. The flanges are also frequently stiffened with brackets, as shown in the right-hand side. The loam bricks, in some cases, are left to yield and be crushed by the shrinking cylinder. In others they are dug out of the mold as soon as the casting has fairly set, but while still red hot; this is necessary in thin pipes.

In the pipe, Fig. 17, the hard dried sand at a a will prevent the shrinkage of the flanges with the pipe, and here, too, the sand must be loosened, and partly dug away before the metal cools. Brackets are also often cast on as shown at the left hand, as a source of strength. In Fig. 11, if cast in steel, the interior sand should be loosened and a portion dug away; the same thing should be done just behind the flanges of Figs. 12 and 13.

The effect of mass on shrinkage is often learned from accidental fractures and wasters. A stout casting will resist shrinkage strains to which a thinner one would succumb; so that the question of easing a mold, or of stiffening a casting with brackets, or radii, becomes closely related to the mass of the metal. Thus, a cylinder (Fig. 16), if 2 inches thick, would be twice as strong to resist shrinkage stresses as one only 1 inch thick. The reason lies mainly in the extra strength, and correspondingly greater elasticity, of the metal. But, besides this, there is a difference due to the more rapid chilling effect which takes place on thin than on thick metal. The chill penetrates quickly in thin, with consequent hardening, rapid setting, and brittle tendencies—evils to be avoided in castings.

That the importance of shrinkage is not exaggerated, may be seen from a moment's consideration. Say it amounts to $\frac{1}{4}$ inch per foot; that, on a casting only

FIG. 17.—PIPE FLANGES WHICH ARE LIABLE TO FRACTURE.

6 feet in dimensions, would equal $1\frac{1}{2}$ inches. If this is hindered, clearly the casting must stretch to that extent, which is impossible; or it must do the other thing—fracture.

Fig. 18 shows the difference between a safe and an insecure design. Above the line a a the design is suitable for cast iron, but unsafe in steel, which would be "drawn," as indicated. Taking out a considerable amount of metal at b renders the design nearly uniform in section.

Wheels and wheel centers are cast in large numbers in steel. One example, Fig. 19, will illustrate the differences already noted in other castings. The lower portion of the figure is a design suitable for iron; the

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upper is suitable for steel, having strong arms, larger radii, and a thinner boss and rim. Provided they are well proportioned, these wheels seldom give much trouble, as they are mostly below 2 feet 6 inches in diameter.

Casting parts together not only interferes with shrinkage, but often causes a thickening of the metal in angles, quite sufficient in amount to cause sponginess like that shown in Fig. 15. Though this alone may not be sufficient to cause immediate fracture, or to produce incipient cracks, the open porous metal is a perpetual, but hidden menace when under strain; while in castings subject to fluid pressure it is a cause of leakage.

To cast big lugs, bosses, and brackets on otherwise plane framings, which can be done in iron, is most injudicious in steel, for they will distort the casting in the most favorable circumstances; while in bad cases they cause incipient cracks, or even absolute fractures. Fig. 20 illustrates a design which, cast in steel, gave much trouble. It is a brake ring cast on the arms of a toothed wheel, and it produced much distortion. This was got over by casting the ring separately, and bolting it up to a circular facing, Fig. 21. It involved extra work in the turnery, but was a good job.

A very important difference between casting steel and iron is seen in the cross sectional area of the ingates, and runners required. Steel cannot be poured safely through ingates so small as those which are used in iron, because the metal is liable to congeal before the mold is filled; hence the reason for the enormous ingates seen in Figs. 2, 10, and 14. The following is the explanation of the difference in steel and iron in this respect. Pig-iron is fluid in proportion approximately to the amount of free carbon that it contains, a fact which is strikingly apparent in the difference between gray iron and the mottled and white irons. A white iron, in which the whole of the carbon is combined, and a mottled iron, in which a considerable proportion of this element is in the combined condition, are both much more sluggish than gray iron, which contains its carbon in the graphitic or free state. This difference is apparent both in the ladle, and in pouring. Steel low in carbon approximates to the condition of white iron, and to that of viscous wrought iron; hence the difficulty of pouring it in thin sections. Steel, "chilling" quickly, fails to fill a mold properly, unless large deep runners are used—large, to fill the mold quickly, and deep, to afford pressure, or "head" to the metal. Taking an extreme example, it would be impossible to pour either steel, white pig-iron, or heavily mottled iron, into the molds for rain-water pipes;

FIG. 18.—DESIGN FOR IRON (ABOVE) AND FOR STEEL (BELOW).

neither would be fluid enough to fill such molds. Only the grayest iron, containing about 4 per cent of graphitic carbon, will fill such thin molds.

But the filling of a mold is only one of the reasons why large ingates are used. A large, deep ingate acts as a "shrinkage head," or "sullage head"—the "head metal" of the molder. The mass of hot metal in it affords a supply to the shrinking mass of the casting below, and itself retains the sullage or dirt, the light and impure metal that would otherwise go down into the mold. The steel caster makes use of very large shrinkage heads—much bigger than the iron founder requires, but with the same objects in view. In many steel castings (e. g., solid pinions, stamps, etc.), there is as much head as casting, or more; and it is only by the adoption of this device that sound metal can be obtained. The heads are sawn, or turned off, and they contain the light, open, spongy, dirty metal, while the castings receive only the sound metal. The large heads, indicated in Figs. 2, 10, and 15, may have from six to eight times the sectional area of those used on iron castings of similar form.

But the remedy of a big head will be worse than the evil it is designed to correct, unless it is applied with judgment. A great mass of metal, as we have pointed out, shrinks beyond the normal, and distorts adjacent parts. Heads are therefore put on the more massive portions of castings; never on a slender rim, or arm, or plate. If this is not practicable, then several smaller heads or runners must be substituted, which is frequently done.

Steel castings are subject, in a much greater degree than those of cast iron, to two other evils—intense hardness, especially on and near the surface, and to blow-holes, and general sponginess. Both these evils were very pronounced in the early days of steel casting, so that between these, and excessive distortion, many castings had to be scrapped. Intense hardness is reduced by annealing. The sponginess is lessened by the practice of casting good heads on, and dead melting of the metal. Thin castings generally suffer more from blow-holes than thicker ones do. As these holes