Kinnaird engine.

KINNAIRD ENGINE.

The REPORT of JOHN SMEATON, engineer, upon the powers and improvements of the engine of Kinnaird, &c.

HAVING received the following propoſitions or meſſage, from the Carron Company, I proceeded to an examination of the premiſes. The meſſage is as follows:

After Mr. Smeaton has viewed the preſent engine, with the ſituation of the houſe, and conſidered any other facts he may think neceſſary to be informed of, the company wiſh to be adviſed which of the following modes they ſhould purſue, in order to be fully able to command the water, and fulfil their contract and after-agreement, with Mr. Bruce.

1ſt. Would Mr. Smeaton adviſe the increaſing the powers of the preſent engine, and to ſink it to the Cox-road coal, and run another back mine?

2dly. Would he adviſe the preſent engine to ſtand where it is, and erect a ſmall additional engine upon No. 10. pit? and if that could be done, and leave room in the pit, (which is nine feet diameter), to draw the coal, and ſave the expenſe of ſinking another pit?

3dly. Or would Mr. Smeaton adviſe the erecting a new engine upon No. 10. pit, or elſewhere, of ſufficient powers to draw all the water from the depth of fifty fathoms?

N. B. The bore of the preſent lift is 14¾ inches, and it was imagined it would require another bore of eight or nine inches to command the water?

Having, in conſequence of the above, examined the premiſes, and made my own obſervations, and having alſo read a printed tract, entitled, "Memorial for the Carron Company, 23d Jan. 1777," and conſidered the plan thereto annexed, my opinion upon the different articles is as follows:

Anſwer to the 1ſt.—In peruſing the printed paper, I find there has been much altercation, whether the engine that has been erected at Kinnaird, either in its former ſtate, with

with a cylinder of 52½ inches, or as at preſent, with a cylinder of ſixty-two inches, was or was not of ſufficient power to draw water from the depths required; now, as it may give ſome light into the whole of the matter before me, to clear this point, I will endeavour to do it before I proceed further.

I do not find that, in all the various reaſonings about the power of this engine, regard has been had to any other circumſtances than the diameter of the cylinder, and the diameter and perpendicular height of the pumps thereto annexed, ſo as to calculate what neat burthen is laid upon each ſquare inch of the cylinder or piſton's area, without paying any regard to the velocity of the engine's motion under ſuch burthen, that is to ſay, to the number of ſtrokes made per minute, and length of the ſtroke, without which it is impoſſible to calculate the quantity of water drawn to a given height, and without which all reaſoning about the effect of the power of an engine, is like attempting to aſcertain the capacity or content of a ſolid, by having only two dimenſions.

In the courſe of my obſervations upon fire engines, through a conſiderable ſeries of years, I have found engines calculated to carry a load, varying from under 5 lbs. to upwards of 10lbs. to the ſquare inch, thoſe carrying a light burthen are expected to go with greater velocity than thoſe carrying a heavy one; ſo that if an engine, carrying 5 lbs. to the inch, goes with double the velocity, or, as I call it, makes twice the journey per minute, to what is made by an engine whoſe cylinder is of equal area that carries 10 lbs. the effects of the power or buſineſs done will be equal, that is, the water actually raiſed from an equal depth will be equal. In the fire-engine, however, as in other machines, there is a maximum that without new principles of power cannot be exceeded; bad proportions of the parts, and bad workmanſhip, may make an engine fall ſhort in any degree of what it ſhould do; but which cannot be exceeded by the moſt accompliſhed artiſts.

Experience has, however, in ſome degree, directed diſcerning artiſts towards a medium, as to the burthen an engine ſhould carry upon the ſquare inch. The original patentees, from ſome of their firſt performances, laid it down as a rule to load the piſton, ſo as but little to exceed 8 lbs. to the inch; but, on more experience, they diminiſhed that load, and amongſt the beſt articles of late years the practice has been to give them at or about 7 lbs. to the inch. Any of theſe will do, if the parts are properly proportioned, but, from a long courſe of very laborious experiments, I have fixed my ſcale near upon, but ſomewhat under 8 lbs. to the inch, including the raiſing the injection

injection water, which is a circumſtance never brought into the queſtion in the ſeveral computations mentioned concerning Kinnaird engine.

A pump $4\frac{1}{2}$ feet below the pavement of the Cox road coal appears to be 104 yards below the delivery drift of the engine pit, which, to allow for one or more ciſterns, call 106 yards; now, according to my ſcale, an engine of ſixty-two inches cylinder, will work a pump 106 yards in height, of near upon $14\frac{1}{2}$ inches, the preſent pump being but $14\frac{1}{4}$ inches, will, therefore, be under the proper load. An engine alſo ſo loaded will go $10\frac{1}{4}$ ſtrokes per minute of eight feet two inches each, that is, it will make a journey of $83\frac{3}{4}$ feet per minute; whereas the preſent engine, in the condition I found it the 2d September laſt, was going $11\frac{1}{4}$ ſtrokes per minute, of ſix feet each, and then taking down its water, there being near twelve fathom water in the pit, occaſioned by a preceding ſtoppage to put in a new ſet of larger pumps for the ground column: now, though it made $11\frac{1}{4}$ ſtrokes per minute, yet they being only of ſix feet each, its journey was no more than $67\frac{1}{2}$ feet per minute, which is leſs than $83\frac{3}{4}$ by near upon one-fourth part of the preſent performance; and as the upper tier of pumps was no more than fourteen inches, we may ſafely lay it down, that the effects of the preſent engine may be improved without augmenting the powers, in the ſenſe I apprehend is meant by the queſtion (that is, by putting in a larger cylinder and pumps in the proportion of four to five), that is, by one full fourth of the preſent performance, and yet take the water from the pavement of the Cox road coal. This ſuppoſes alſo, that all the water is let down to the bottom of the Cox road coal, and then drawn up again, whereas the water being detained at its preſent random of the engine pump foot, it is probable, that a ſmall bore would draw the water from the Cox road coal; and alſo in running a back mine underneath the former to the verge of the boundary of the eſtate, which is all I apprehend can be expected from the company in literal performance of their after-contract, as they cannot be required to find the main coal within the boundary of the eſtate, unleſs it were there; and if the company have nothing further in view than the literal accompliſhment of their contract, this ſeems not only to be the beſt, but the only way by which it can be done.

In comparing the performance of an engine of ſixty-two inches cylinder, ſuch as I have ſtated it when improved, with what it performs at preſent, or probably ever has done, it may poſſibly be inferred, that the engine at Kinnaird has always been defective in conſtruction, ſize, or ſtrength, to what it ought to have been in conformity to the leaſe; but here I muſt remark, that if it was not defective in any of thoſe reſpects, according

according to what was deemed the beſt mode of practice at the time it was erected, it could not be incumbent on the company to perform what was then not known, as no one could, or can foreſee what improvements in theſe machines could, or actually have been made; and as I date the improvements mentioned when brought into the field to ſo late a date as the beginning of the year 1774, this is long poſterior to the erection of this engine.

Kinnaird engine appears from the firſt intended to work a fourteen inch pump, which is a larger ſize than has been commonly calculated upon, to wier a coal whoſe quantity of water was unknown: twelve inches in this caſe has generally been deemed ſufficient.

A cylinder of 52½ inches to work a pump of eighty yards in height, which appears to be ſufficient for winning the main coal at the place where the engine now ſtands, and of fourteen inches bore, would lay no more, including injection water, than $7\frac{7}{10}$ lbs. per ſquare inch upon the piſtons, which is very nearly what I have ſince proved by experiments to be the beſt; and if a 52½ inch cylinder were fitted to this work, as we may well ſuppoſe in the interval between Martinmas, 1760, when the leaſe commenced, and the 31ſt of December, twelve months following, when the viſitors ordered the company to go down to the Cox road coal, and there run a level mine to cut the main coal to the dip; I ſay, if in the ſpace of thirteen months, a 52½ inch cylinder were fitted to this work, it was very natural, and I look upon it at the time adviſeable, to try how far they could go with this cylinder, ſince no one can ſay with certainty what is in the bowels of the earth, either of ſtrata or water, till they are pierced; and the rather, becauſe if they then had in proſpect, what I am informed was really the caſe, that they ſhould take in a conſiderable feeder at the middle of the pit to the ciſtern of the upper column of pumps, then they had a probable chance to go down with a pump of leſs ſize to the pavement of the Cox road coal; and a leſs pump was actually put in, and there continued till the new pump was put in (as I am informed) the laſt ſummer. Now, if the upper column of pumps were fourteen inches, and a lower column of thirteen inches had been found ſufficient to have drawn the water from the Cox road coal, theſe would have laid no more burthen upon the piſton than 9½ lbs. upon the inch, which is yet conſiderably under the limits of the burthen, which before that time I had ſeen in uſe, and at that time, ſo far as I know, no man had proved what was beſt. It was, however, then commonly known, that the engine under this load would go ſlower than if the burthen were lighter; but for ought that then appeared, or was known, it might be expected to draw more water than the ſame cylinder would have done, if fitted with twelve-inch pumps, which, from the Cox road coal, including injection, would have laid no more upon it than $7\frac{7}{10}$ to the inch and which, as already obſerved, ſpeculatively

culatively conſidered, might be deemed at this time an adviſeable power to attempt the winning of a colliery whoſe quantity of water is not known; and had the ſtrata laid as ſuppoſed in the after-agreement of the 31ſt December, 1761, the work done accordingly, and the water grown eaſier, by continuance of working, as frequently proves to be the caſe, then there had been no reaſon of complaint of the inſufficiency of the engine.

It happened that in the year 1769, curioſity and obſervation (being in theſe parts) led me to take a view of Kinnaird engine, which was then working with the fifty-two and a half inch cylinder; the minutes of this view are now before me, and it appears to me that this engine was doing as much work in proportion to its ſize of cylinder, as the generality of engines at that time did, of which I examined a good many, being then preparing for my own experiments.

This engine, however, as I underſtand, by unlooſing more water, was afterwards overpowered, and the Carron company did then what is uſually done in the caſe, put in a larger cylinder, increaſing it from fifty-two and a half to ſixty-two; the pump being too great a load for the ſmaller cylinder, remaining as before; the effect of which alteration would doubtleſs be by diminiſhing the load upon each inch of the piſton's area, to increaſe the velocity of the motion, and thereby with the ſame pumps to draw more water; and which water having ſince again increaſed, the ſixty-two inch cylinder is now in want of a further increaſe, or of improvements that may be tantamount. It, however, may now be made a queſtion, whether the building was originally made ſo as to be likely to be ſtrong enough for ſuch an increaſe of power, becauſe, if it was not, the Carron company muſt be allowed to be blameable otherwiſe, in building an engine incapable of a greater power than that originally deſigned, when it frequently happens that an increaſe of power in theſe caſes is wanted.

In this reſpect, as I find the beam wall above five feet thick, and the other walls proportionable, I conclude it built with intention, if occaſion required, to receive a greater cylinder than the original one of fifty-two and a half inches; its dimenſions are fully ſufficient for a cylinder of the ſize put in, and of ſuppoſition of the foundation being good, I ſhould not ſcruple to put in a cylinder of ſeventy inches; a conſiderable ſettlement has however happened in the beam wall directly under the working beam, ſince the putting up of the ſixty-two inch cylinder; the queſtion is therefore, whether this ſett has happened through want of dimenſions, or inſufficiency of the work, or from ſome other cauſe?

As I am informed, ſome feet under the beam wall there is a ſtratum of ſand which, though ſufficiently compact to bear weight, will not bear the leaſt oozing of water, if it can get looſe, as is commonly the caſe: this ſtratum I underſtand was ſunk through in ſinking the little ſtaple pit for the injection pump; now, in wet ſeaſons, a very ſmall drainage of water from this ſtratum of ſand into the ſtaple pit will bring particles of ſand along with it, and by continuance of the ſame for years, though almoſt imperceptible in a ſmall ſpace, is very capable of producing the effect now ſeen, and though it is probable that this would have appeared before this time, though the fifty-two and a half cylinder had remained, yet the greater the agitation cauſed by the larger cylinder, and perhaps wet ſeaſons co-operating therewith, may of late have brought on this appearance in a greater degree; and it is an argument of the ſolidity wherewith the walls of this building have been raiſed, that the ſettlement is perpendicular, being in the middle under the beam, and near the ſtaple pit, while the ſide walls at a greater diſtance, and leſs preſſed, ſtand where they were built.

The propereſt way to put a ſtop to this evil, which, from the nature of it, above deſcribed, muſt be growing, will be to put into the ſtaple a cradle or tub, cloſe boarded, ſo as nearly to ſhut up the water, but effectually the particles of ſand iſſuing from this ſtratum, and if need be to continue the boarding or ſheeting on the ſide next the engine of the main pit. This effectually done, the ſettlement will go no further, but if it be not, recourſe muſt be had to buttreſſes to diſcharge the weight and action of the beam ſideways, which buttreſſes had beſt be founded near the ſurface, and if need be, ſupported by piles driven thereunder; it is impracticable to rebuilt the beam wall in a going engine, otherwiſe, if time would permit, an arch might be caſt over the ſpace liable to ſettle.

Furthermore, as it appears that the plan of the engine is ſuch as to be capable of having as many boilers, and of as large ſize as in event might be wanted; in this reſpect alſo it is adapted to an enlargement of the powers, and though it is by no means ſuch a conſtruction as I ſhould now recommend, yet at the time of the erection, things appear to have been done and diſpoſed in ſuch a method, as was moſt generally approved; in ſhort, though the Carron company do not ſeem to have been ſparing in the execution of ſuch things as from time to time have appeared for the beſt, yet they ſeem to have been particularly unfortunate in receding from the firſt propoſed ſituation of the engine; for had they perſevered in getting through the firſt difficulties of that ſituation, every thing after would have become eaſy, and many heavy expenſes, and many diſappointments

ments avoided. Having now diſpatched the immediate ſubject of the firſt queſtion, as well as what naturally aroſe out of it, I proceed to conſider the ſubſequent.

In anſwer to the 2d and 3d queſtions, which I ſhall take together, becauſe they both of them ſeem to imply the giving up any idea of a ſpecific literal performance of the after-agreement of the 29th of December, 1761, in reſpect to the ſinking of the Cox road coal, &c. and to put the matter from what has turned, upon what is beſt now to be done, in order to win out of the Kinnaird eſtate as much coal as can be got out of the main coal, and ſuch of the upper ſeams as it may ſeem eligible to get.

It is now ſtated to me, that the pavement of the coal, at the pit No. 10, lies ten feet below the foot of the preſent engine pump; it appears therefore neceſſary in order to get the coal there, to erect an engine of ſome kind at the pit No. 10, and the queſtion is, whether a ſmall engine, with pumps of eight or nine inches, to draw ſuch quantities of water as cannot be commanded, in point of level, by the preſent engine, or at once to erect an engine of ſuch conſtruction, power, and ſize, as ſhall command the water of the whole field at that place? and I cannot heſitate in ſaying, that I look upon it to be the ultimate intereſt of the company, under the circumſtance of waiving all other agreements, to build a new engine at pit No. 10, that ſhall at once be likely to command the water of the whole field.

To begin a work with ſuch a power as is generally found to be competent, though from unforeſeen accidents it afterwards proves to be otherwiſe, this muſt be looked upon among the number of uncertainties that attend theſe affairs; but now that the field is in a great meaſure explored, and the quantity of water inveſtigated, to erect any thing that has not the probability of being fully competent, would be unpardonable. It is ſtated that a nine-inch bore may be wanted in aid of the preſent engine: to work this with proper effect at No. 10 pit, will require a thirty-ſeven or thirty-eight inch cylinder to be erected new, with a houſe, and all its furniture; but to do this work, and all that I found doing at the preſent engine will be done by a ſixty-five inch cylinder, properly conſtructed at No. 10 pit; yet to provide for all contingencies that can reaſonably be expected, I would adviſe the company to put on an engine of the firſt rate, viz. an engine of ſeventy-two inches cylinder, which will work pumps of ſeventeen inches bore, and draw one-fifth more water than the laſt-mentioned engine, and in caſe there ſhould be no increaſe of water beyond the preſent, will do its buſineſs in leſs than fifteen hours per day: the great advantage of having time to ſpare is well known.

Much

Much in cafes of this kind depends upon the eſtimates of expenſes, but to make an accurate eſtimate of two fire engines would of itſelf take much time, and when done, the balance of the account would be involved in the uncertainty that would attend the altering and putting the preſent engine into a good and durable way of performing its duty. I muſt therefore, at preſent, content myſelf with ſuch opinion as to expenſes, as ariſes from a general view of the ſubject, and in this way I cannot think that the company can poſſibly, in the firſt inſtance, ſave £500 by erecting a ſmall engine upon pit No. 10, rather than the large one recommended, to ſet againſt which difference, they will firſt have the materials of the preſent engine. 2dly. They will ſave conſiderably in engine keepers, for the preſent engine will require the ſame number as at preſent, with an additional number for the new engine, whereas, an engine upon my plan of ſeventy-two inches cylinder, will conſume no more coals than the preſent engine requires per hour, when there is ſtandage for the water, it will be worked by ſingle ſhifts. 3d. The whole of the coals conſumed by a leſſer engine will, for the ſame reaſon, be ſaved. 4th. Which is moſt material, as the preſent buſineſs will be done under fifteen hours per day, there will be more allowance for additional water, and conſequently more certainty in carrying the works regularly on.

I have only now to add, that a ſett of ſeventeen-inch pumps, in three lifts, may ſtand in a pit of nine feet diameter, and after brattiſhing them off entirely, leave five feet of the pit's diameter clear, for drawing coals.

J. Smeaton.

Austhorpe, 9th October, 1779.