the extension beyond the elastic limit. But all these proposals are undoubtedly worth trial in practice. Dr. Joule's plan has the merit of affecting the plates by both heat and pressure, thus bringing them under every day conditions.

(To be continued.)

Temperatures and Pressures of High Pressure Steam. By R. A. PEACOCK, C.E., Jersey.

From the London Artizan, June, 1865.

An examination of the following table—which has never been published before, and, with the exception of Dr. Fairbairn's experiments, is quite new—will satisfy the reader that from 25 lbs. per square inch up to 411·6 lbs. per square inch, the temperature increases as the $4\frac{1}{2}$ root of the pressure. The greatest variation from M. Regnault's experiments is with his temperature of 300° Fahr.; such variation, however, is less than $\frac{1}{4}$ per cent., viz: ·232, or 1 in 431. It will be further observed that even with regard to that small variation, the result ought to be considered as modified by the very close approximation of the calculation to Dr. Fairbairn's experiments with a temperature only a little less, viz: 292·53° Fahr., for which the calculation gives a difference of only ·017 per cent., or 1 in 5882. With M. Regnault's temperature of 410° Fahr., the calculation is all but identical, the difference being only ·002 per cent., or 1 in 50,000, while with his last temperature, viz: 447° Fahr., the difference between experiment and calculation is still unimportant, being no more than ·159 per cent., or 1 in 629. And it may be further observed, that the formula, *Temperature increases as $4\frac{1}{2}$ root of pressure*, is, so to speak, still more moderate than M. Regnault's own formula; because it will be seen that the former requires 447·71° to give the pressure of 411·6 lbs., whereas M. Regnault's formula gets that pressure with 447° Fahr. only. That is to say, if both formulæ were to be applied (hypothetically) to calculate very high temperatures of, say, 2000° or 3000° Fahr., M. Regnault's formula would give greater pressures than the other. Probably the means do not exist for ascertaining how far either formula differs from fact at those high temperatures.

Yet, although exact knowledge does not exist, we are fortunately not without some indications of the force of steam pressure at very high temperatures. The Rev. John Michell wrote a very valuable paper, in which he contended that earthquakes were caused by steam,* which paper does not appear to have gained as much consideration as it probably deserves. He says that in casting two brass cannon "the heat of the metal of the first gun drove so much damp into the mould of the second, which was near it, that as soon as the metal was let into it, it blew up with the greatest violence, tearing up the ground some feet deep, breaking down the furnace, untiling the house, killing many spectators on the spot with the streams of melted metal, and

* Phil. Trans. R.S., 1760, vol. xi., p. 447, &c.

Pressures per Square Inch.	Regnault's Ex- periments.	Dr. Fairbairn's Experiments.	As 4½ Roots of Pressures.	Differences.	Differences per cent.
lbs.	Temp. F. deg.	Temp. F. deg.	Temp. F. deg.	deg.	deg.
24.998	240		240.244	— .244	— .102
26.5		242.90	243.375	— .475	— .195
27.3518	245		245.093	— .093	— .038
27.4		244.82	245.188	— .368	— .150
27.6		245.22	245.585	— .365	— .149
29.8753	250		249.946	+ .054	+ .022
32.5899	255		254.824	+ .176	+ .069
33.1		255.50	255.705	— .205	— .080
35.5005	260		259.715	+ .285	+ .110
37.8		263.14	263.362	— .222	— .084
38.6169	265		264.617	+ .383	+ .145
40.3		267.21	267.137	+ .073	+ .027
41.7		269.20	269.17	+ .03	+ .011
41.9587	270		269.543	+ .457	+ .170
45.5259	275		274.474	+ .526	+ .192
45.7		274.76	274.71	+ .05	+ .018
49.3332	280		279.417	+ .583	+ .209
49.4		279.42	279.50	— .08	— .029
51.7		282.58	282.34	+ .24	+ .085
53.3953	285		284.374	+ .626	+ .220
55.9		287.25	287.29	— .04	— .014
56.7		288.25	288.20	+ .05	+ .017
57.722	290		289.34	+ .66	+ .228
60.6		292.53	292.48	+ .05	+ .017 = $\frac{1}{5882}$
62.328	295		294.319	+ .681	+ .231
67.2231	300		299.306	+ .694	+ .232 = $\frac{1}{431}$
72.422	305		304.302	+ .698	+ .229
77.9345	310		309.303	+ .697	+ .225
83.7802	315		314.315	+ .685	+ .218
89.9689	320		319.332	+ .668	+ .209
96.5104	325		324.352	+ .648	+ .200
103.4292	330		329.381	+ .619	+ .188
110.7302	335		334.412	+ .588	+ .176
118.433	340		339.446	+ .554	+ .163
126.5523	345		344.486	+ .514	+ .149
135.1028	350		349.527	+ .473	+ .135
144.0992	355		354.565	+ .435	+ .123
153.5562	360		359.614	+ .386	+ .107
163.4934	365		364.660	+ .340	+ .093 = $\frac{1}{1075}$
173.9206	370		369.705	+ .295	+ .079
184.8574	375		374.750	+ .250	+ .067
196.3234	380		379.795	+ .205	+ .054
208.3284	385		384.838	+ .162	+ .042
220.8871	390		389.876	+ .124	+ .032
234.024	395		394.918	+ .082	+ .021
247.7538	400		399.949	+ .051	+ .013
262.0912	405		404.980	+ .020	+ .005
277.0509	410		410.007	— .007	— .002 = $\frac{1}{50000}$
292.6525	415		415.029	— .029	— .007
308.9156	420		420.047	— .047	— .011
325.85	425		425.058	— .058	— .014
343.4753	430		430.063	— .063	— .015
350.7224	432		432.063	— .063	— .015
411.6*	447†		447.71	— .71	— .159 = $\frac{1}{629}$

* = 28 atmospheres, and † = 239.56 centigrade. See Rev. R. V. Dixon's "Treatise on Heat," p. 183.

scalding others in the most miserable manner." These great effects were evidently produced by the steam of a few ounces of water only, for it is called merely "damp," and it must, therefore, have been very powerful steam. Now, according to the late Professor Daniell, F.R.S., brass melts at 1869° F., but the heat of the steam could not have been as much as that, because, amongst other reasons, a portion of the heat must have been taken up by raising the temperature of the "damp," and the "mould," and the neighboring sand. If the temperature of steam could have been 1869° F., the hypothetical pressure would have been by the formula, 114 tons per square inch; but the real force consequent on the reduced temperature most likely was considerably below 100 tons. What is intended to be inferred is, that the pressure of steam continues to increase at all events as high as up to water converted into steam by an initial heat of 1869° F. The law of increase may either be according to either of the formulæ, or to some of the other well known formulæ, or to some other unknown law, but at all events the force *had* continued to increase.

The columns headed "Pressures per square inch," so far as they relate to M. Regnault's experiments, are reduced from Table I, pp. 259-260, of the Rev. R. V. Dixon's "Treatise on Heat,"* where he gives the pressure or force in inches of mercury. He was elaborately accurate in reducing M. Regnault's temperatures and pressures to English denominations, having calculated the values of the constants from Vlacq's tables, in which the logarithms are given to ten places of decimals, (p. 252.)

Further particulars of this formula appeared in the *Artizan* of January and February, 1864.

The present writer exhibited before the Mathematical and Physical Section of the British Association at Bath (but did not read) a MS. containing about sixty evidences of the presence of water in some of its forms, in every species of natural disturbance of the earth's crust. Additional evidences have since been collected, and the whole number now amounts to about seventy; and a summary of these evidences gives the following results:

Humboldt, who, perhaps, personally inspected more volcanos than any other man who ever lived, and Sir Humphrey Davy, both condemn the alkaloid theory as co-operative only; and

1. We have Humboldt, Davy, Lyell, Von Buch, Dana, Sir William Hamilton, Dr. Scherzer, and three anonymous writers, testifying to the ejection of abundance of steam from volcanos generally, and some of them from Vesuvius in particular.

2. Steam is ejected from earthquake fissures.

3. It is *said* that steam is exclusively the moving force in geysers, and *proved* that it issues from them in great force and abundance.

4. Large rocks are ejected by steam.

5. Submarine volcanos necessarily produce steam, and one of them has been active for 2000 years. Earthquakes often accompany. Steam was very active when Graham Island rose from the Mediterranean.

* Hodges and Smith, Dublin, 1849.

6. In 1822, at Galangoon, in Java, the waters of the river Kunir, which flowed from the flanks of a volcano, became for a time hot and turbid. About two months after there was a loud explosion, and immense columns of hot water, boiling mud, burning brimstone, ashes, and lapilli were projected like a water-spout, with prodigious violence, and to a great distance. The first eruption lasted nearly five hours, and on the following days the rain fell in torrents, and the rivers, densely charged with mud, deluged the country far and wide. At the end of four days, a second eruption occurred more violent than the first, in which hot water and mud were again vomited, and great blocks of basalt were thrown to a distance of seven miles. There was at the same time a violent earthquake, and 2000 people were killed.

7. Hot or boiling water and rocks are ejected from volcanos, and sometimes accompanied by earthquakes. A large lake has its level lowered during a volcano and earthquake, and two small rivers disappear and break out again as hot springs.

8. Water, often hot, is ejected from earthquake fissures, and from risings and sinkings of strata.

9. Earthquakes are fed by water.

10. Deposits of water, ice, or snow are ready to descend into volcanos by gravitation.

11. Active volcanos are fed by water, and absorb all the rain which falls upon them.

12. Volcanos in action, earthquakes, hot water, and increased heat of hot springs, are sometimes all connected together.

13. The lava of five volcanos emits copious volumes of steam or gas.

14. In extensive reading on the subject, the writer has found no reason to believe, nor any allegation, that steam or its components is ever absent.

15. "A deplorable accident has lately happened at Etna by an explosion caused by the contact of burning lava with some cistern or watercourse, by the effects of which a number of sappers are reported to have lost their lives, but the particulars are not known."* Thus steam and hot water have literally a great deal to do with volcanos and earthquakes, for steam cannot be idle.

The ancient Greeks used to personify everything. Would they not, if they had known all these things, have been likely to represent Etna pointing to the explosion of the cistern as the principle of her own explosions? And ought not the same point to be a grave question now?

Sir Henry de la Beche and Mr. L. L. Dillwyn made experiments† by which they found that Cornish granites and elvans melted with a heat about equal to that required for melting malleable iron, which is the greatest heat that can be obtained in a smith's forge. But even

* Mr. J. J. Jeans, British Vice-Consul at Catania, Feb. 4, 1865. See *Illustrated London News*, Feb. 25, 1865.

† Sir H. de la Beche's "Cornwall," p. 191, foot note.

with this great heat black non-lithia micas remained unfused. We may, therefore, safely assume, for these and other reasons, that the heat of melted lava is not less than 3000° F. But since we have seen that the force of steam has increased according to some unknown ratio up to an initial temperature of 1869° , it would be contrary to all precedent, and therefore rash to assume that there is not also a further increase with 3000° .

Supposing, for the sake of argument, and by the way of illustration, (for the moment only,) that the temperature continues to increase as the $4\frac{1}{2}$ root of the pressure until the net thermometrical temperature of the steam has become 2200° F., which Professor Daniell found is the heat of melted gold. Then the (hypothetical) pressure would be 237,494 tons per square inch, which, by calculation, would suffice to propel a certain large mass of granite from a supposed focus three miles below sea-level up to one mile above sea-level—in all four miles of vertical height, inclusive of the resistance of the air, which is very great. It would follow, then, that it is *possible* that there *may be* such a thing as steam powerful enough to produce the greatest effects of earthquakes and volcanos, for 2200° is by no means the maximum temperature attainable.

For the Journal of the Franklin Institute.

Cut-offs.

The controversy between the Navy Department and the builders of the *Algonquin*, enlivened by the trenchant letters of the constructor of her engines, has forced on public attention the subject of expansion by cut-offs. The sympathies of many practical men are with the builders. They endorse their confidence in the superior qualities of the engines, and their defiance of official opponents. Still, the principles of physics, on which the result depends, are inexorable and insensible to moral suasion or censure. There are those who think the mighty agent, upon which progress depends more than on anything else, has passed through every form and phase of trial, and that its value as a motor is exhausted in modern engines; others, with more reason, believe that, so far from our knowledge of it being complete, much of importance is yet to be acquired. Unacquainted with the parties contending and their experiments, without a shadow of interest in cut-offs, or the slightest prejudice in favor of or against them, I think it has happened to them as to other devices, to which credence has been given without due examination, and opinions taken up on trust. At the risk of having the remark applied to myself, I think they are imperfectly understood. The following thoughts are thrown out with the sole view of aiding in the discovery of the truth.

To economize steam by expansion has been a desideratum for well nigh a century, and nothing conclusive has been attained. Conflicting opinions are still rife, and the government has charged a commission of experts to solve the problem by a fresh set of experiments. I have