

REVIEW OF THE REPORT ON THE IRWIN INJECTOR.

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The report of the Committee on Science and the Arts, published in the February number of the JOURNAL, and containing a series of experiments upon the injector and ejector of J. H. Irwin is valuable rather for the experiments themselves than for the deductions and views gathered from them. The generalization of observed facts, and their subjection to known laws and principles, is, however, the most important part of experimental research. It is by this means that new relations are discovered, and better knowledge is gained, without which improvement must be more or less accidental and uncertain.

A crude general theory for the action of injectors is well known to all who are familiar with the instrument; but something more definite is needed before it is possible to determine theoretically the performance of an injector under various conditions from the dimensions of its parts, or what is perhaps of greater importance, to determine the proper proportions for certain desired results.

The present subject is surrounded by so many difficulties and apparent contradictions that any attempt to develop a satisfactory theory upon fundamental principles can hardly be expected to be at once successful. It is therefore only in the hope that a better understanding may ultimately be reached that the following theories and criticisms are offered :

In the first place, it has been claimed for the Irwin Injector that it is constructed on a certain fixed rule of proportion of parts, the discovery of which proportion is the important feature of the invention. The value of the discovery is further claimed to be demonstrated by experiments showing that an injector constructed on this new formula has a wonderful power of augmentation.

The determination of this property of the injector seems to have been the primary object of the experiments, while another more important one, namely, that of "range," has been left in the background.

With this supposed object in view the results are perhaps as good as occasion may ever require, but, with few exceptions, the demand upon

an injector is not to overcome pressures greatly in excess of the steam pressure, but to be able to supply water to a boiler at the rate of evaporation, whether this be slow or rapid, and this ability to vary the quantity of delivered water is what is understood by the term "range."

It is well known among manufacturers of these instruments that one desideratum can only be perfected at the sacrifice of others, and that injectors which give good results for range have less power of augmentation, and *vice versa*.

It is therefore difficult to understand how any rules for the proportions of parts can be made general; and how an injector, which gives such good results for augmentation as that of Mr. Irwin, could have been made, as we are led to suppose, according to a law governing its economic action.

The power of augmentation depends upon the velocity and density of the fluid jet in its passage from the combining to the delivery tube, the velocity, in turn, depends upon the proportion of water to steam, and the density, to some extent, upon the duration of their contact before leaving the combining tube.

The less the proportion of water thrown, the higher the velocity and temperature of the mixed water and steam, the slower the rate of condensation and the shorter the time of contact, from which it can be inferred that the proportions favorable to augmentation would be a larger steam nozzle with a longer combining tube than could reasonably be used on an injector designed for economic action. When the injector is used as a boiler feeder its action is economic under all circumstances, and its duty, as stated in the report, is comparatively unimportant, but when used as an ordinary pump the increased temperature of the feed water may no longer be regarded as a useful form of energy, and the economy must be measured by the mechanical effect produced.

For such a purpose, then, the greater the amount of water thrown, and consequently the slower the velocity of the fluid jet within the working limit, the greater the economy as far as mechanical effect and the slight losses by radiation are concerned. The water pressure is in most cases equal to that of the steam producing the jet, and the problem long sought has been to increase the range, that is, to vary as much as possible the quantity of water thrown, in order that a boiler may always be supplied at the rate of evaporation.

The greatest range can be obtained when the greatest possible amount of water is thrown with the steam jet full open. As the steam and water are shut off, the velocity of the mixture must increase, while its density must necessarily decrease, from the fact that a smaller quantity of fluid has to pass through the same sized openings. In order that the fluid of lighter density may overcome a constant resistance, it is evident that its velocity ~~must~~ be increased, and this can only be done by the reduction of the ratio of water to steam.

To determine theoretically the possible range for an injector, it is necessary to know the velocity of efflux of steam and the precise nature of the causes which operate to break the jet.

The most obvious of these causes are want of velocity and density, pressure at the overflow and friction. When the effects of friction and pressure at the overflow can be accurately determined, the injector itself should furnish the best data for computing the velocity of steam, upon which authorities so widely differ. The effects of friction become apparent in the augmentation and range of similar injectors which differ principally in size, and might be determined from a comparison of the results.

The quantity of water delivered depends more upon the conditions at the overflow than upon the pressure overcome, and experiments have shown that there is often no difference between the quantity delivered into the atmosphere and that delivered into the boiler. The reason is clearly because it is not possible to transmit pressure through an open jet except by the pressure surrounding it, and so long as the conditions at the overflow remain constant, the velocity and density of the jet on leaving the combining tube are independent of the pressure afterwards overcome by it. When there is pressure at the overflow the force of the jet will be affected by the density of the fluid producing that pressure as well as by the pressure itself, and when water accumulates, the power expended in its agitation must be sufficient to explain in part the higher degrees of augmentation which can be obtained with waste at the overflow. In the absence of more accurate knowledge, approximate data for computing the velocity of steam might be obtained from an experiment of the following kind:

Let the injector be in full operation, with overflow open, and let the resistances to the delivered water be increased until waste commences, then the pressure equivalent to the combined effects of pressure and friction has become equal to that due to the average velocity and

density of the jet. The quantity of water delivered and the total pressure overcome are sufficient data for determining the velocity and density of the jet. The velocity of the jet multiplied by the ratio, plus one of water to steam, will give the velocity of steam. In this experiment, the larger the injector the smaller the effect of friction, and the more reliable will be the result.

It is claimed in the report that the free entrance of atmospheric air at and through the overflow gives a clear gain to the extent of one atmosphere in the same direction.

In this case the injector was running without waste at the overflow, and no water pressure could accumulate by its stoppage; consequently there appears to be no reason why the phenomenon could not have been attributed to the suction of air by the jet into the delivery tube, nor why an increase of pressure might not have been effected in the same way by increasing the water supply.

The injector evidently had not enough water for the steam used, and it took in air whenever the opportunity offered.

The fact, as reported, that the temperature of the delivered water fell from 136° with overflow closed to 127° with it open, some steam being shut off to keep the water pressure constant, is not conclusive proof that "the steam so shut off was undoubtedly saved," as we are led to infer by the presence of the atmospheric air.

It is highly probable that the temperature of the delivered water could have been reduced in the same way with the overflow closed, and it is to be regretted that after the instrument had been adjusted to the water pressure of 83 pounds, with overflow open, that the temperature and pressure of the delivered water was not again taken with the overflow closed. In fact, the fallacy of the above assertion can be shown by Experiment A itself; for, as we see, the temperature of the delivered water was 138° with overflow open and only 136° with overflow closed; hence, more water must have been passing through the injector when the overflow was closed than when it was open; and yet, as we see further, 10 pounds more resistance was offered by the globe valve in the delivery pipe to the passage of the smaller quantity of water. The conclusion is inevitable that something besides water was taken in by the jet, and this must have been the air admitted through the overflow.

With regard to the experiments themselves, and the calculated columns in the tables, but one objection, of minor importance, can be

made, while great praise should be accorded for the manifest care and labor on the part of the committee in their preparation.

The objection made is to the method of computing the percentage of error given in column 20. By reference to the report the following expression will be found

$$(1 + X) D - X F = R + E, \quad \text{in which}$$

R = the total heat of 1 pound of steam for the observed pressure taken from Regnault's tables.

D = the specific heat of the delivered water for the observed temperature.

X = the weight of feed-water delivered per pound of steam.

F = the specific heat of the feed-water for its observed temperature.

E = error of the experiment.

The objection is made on the ground that the total heat of steam as given in Regnault's tables is measured from an arbitrary zero, 32°F., which, while it does not affect the value of E , has, nevertheless, considerable influence upon the value of the expression $(1 + X) D$, which forms the denominator of the fraction in computing the percentage.

It would seem logically more correct to determine the percentage of error from a comparison of the calculated and actual quantities of steam used, and this would then give a definite amount independent of any assumed zero of temperature. For instance, in the first experiment 7 per cent. is given as the percentage of error, and we also have from the table:

Weight of feed-water lifted, = 471.5 lbs.

Temperature of feed-water, = 62.5°

“ “ delivered water, = 104°

Increased temperature of feed-water, = 41.5°

Thermal units abstracted from steam, 41.5×471.5 , = 19567

Thermal units in 1 pound of steam above 104° from

Regnault, = 1086

The theoretical weight of steam condensed would therefore be $\frac{19567}{1086}$ or about 18 pounds.

The observed weight of condensed steam was 20.5 pounds, a difference of 2.5 pounds.

This difference may be due to priming, radiation, or to errors in observation, but the error of the experiment as deduced from it will be $\frac{2.5}{20.5}$, or about 12 per cent.

It is hoped, in closing this review, that the suggestions and theories advanced may lead to a more thorough and scientific study of the subject than can be derived from experiments designed to show the performance rather than to determine precisely the causes which limit and control the action of injectors.

EYE-MEMORY.

A Lecture delivered before the Franklin Institute March 29th, 1880,

By CHARLES G. LELAND.

(Continued from page 336.)

The writers on the Kindergarten, and on object-teaching in connection with elementary drawing, have hit on a great truth in their endeavor to teach children to form *definite* impressions. But I doubt if any of them, or any one living, knows how indefinite all our memories of objects are, compared to what they might be. Object-teaching causes children to learn the appearance, names and qualities of things. "And many persons," says Mrs. Horace Mann, "object to it because it is playing with things, and the opposite of study." The cultivation of eye-memory must, however, be admitted by the greatest enemy to all new ideas in education, to combine all the discipline of intense study with all that is useful in object-teaching. It is the very opposite to anything like loose thinking or vagueness. It calls for the closest observation and the greatest exercise of the memory conceivable. Therefore it is good discipline for the mind, therefore it should be a legitimate branch of education. But be it observed that this practice of the visual memory, while requiring intense application and much practice, is not disagreeable in the sense in which much study is disagreeable. In fact it cannot be pursued with profit an instant after it becomes wearying. As soon as you tire of it, then, in the words of Westwood, "the visions flee and the dreams depart." The memory will only work of her own accord at this; she will only remain as a willing guest. Force her, and she flies.

On the other hand, *success* in the practice of visual memory is so encouraging that after we once realize our progress the most strenuous effort becomes in fact a voluntary pleasure. I conceive that for its cultivation classes should be formed, at which maps, pictures or any