THE WARFARE OF THE GODS

By F. W. PRESTON

Editor's Note: So that there would be maximum news coverage of Operations Crossroads, the Army and Navy issued invitations to attend the bomb tests to a selected group of publications in specific fields. The Glass Industry was chosen to represent the glass field and John T. Ogden attended the first bomb explosion at Bikini. Dr. Preston was present at the second test.

It is impracticable for a monthly journal like The Glass Industry to compete with the daily press, the radio commentators, or the movie newsreels in picturing the blasts: nor was it possible for either of our emissaries to learn much of specific importance to the glass manufacturer. This may come later. Both Mr. Ogden and Dr. Preston are scheduled to report their personal experiences and reactions to the Glass Division of the American Ceramic Society at the Columbus meeting later this month (September 14th), but meantime Dr. Preston sent us some ruminations on atomic bombs and thunderstorms which we felt might be of interest.

July 26, 1946
(Bikini Date)

Writ aboard the
U. S. S. Appalachian

I am in the position of Ben Backstay, when he fell overboard.

"They threw him out some tackling
to give his life a hope,
But, as the shark bit off his head
He couldn't see the rope."

The bomb went off, and I suppose it damaged some glassware: or maybe the glassware stood up remarkably well. But as the ships near the blast are at the bottom of the Lagoon, and those that floated are so "hot" with radioactivity that they cannot be visited, I haven't been able to find out.

Off the coast of California for eight hundred miles there is a nearly continuous blanket of quilted cloud, a thousand feet or so above the sea. Beyond that, as one nears Hawaii or continues on to Kwajalein and Bikini, the cloud structure is more open. The whole skyscape is dotted with cumulus clouds, mushrooming up here, there and everywhere, not unlike (though not entirely like) the atomic bomb cloud itself. This suggests some comparison of "thunderclouds" and atomic experiments.

The energy released in an atomic bomb explosion is about 10^{21} ergs. This is no secret, for the fact has been announced many times, but usually in an indirect language. For instance, President Truman declared the bomb to be equivalent to about 20,000 tons of T.N.T., and the heat of combustion of T.N.T. is known, being around 1,000 calories per gram of the explosive, and a calorie is 4.2×10^7 ergs. The information may also be deduced from the Smyth Report, which places the mass of uranium in the bomb at between 1 kilogram and 100 kilos. This leaves us some latitude, but the other published data lead us to suspect that the mass disappearing in the reaction is about 1 gram, which is equivalent, by the Einstein equation[1], to about 0.9×10^{21} ergs. Or again we have Commander Revelle's statement that if all the energy of the bomb were used to heat the water of Bikini lagoon, it would not raise the temperature of a square mile of the lagoon by as much as one degree. The published maps of the Hydrographic Office show that the lagoon is somewhat uniformly about 170 feet deep, so Revelle's statement means that the energy of the explosion is well under 10^{22} ergs and is probably about 10^{21}.

Now 10^{21} ergs is approximately 36,000,000 H.P.-hours. It is enough to keep a fifty-thousand horse-power plant going for a whole month: it is enough to drive a large liner or battleship at normal cruising speed completely round the world. If we assume that in current practice it takes eight million B.T.U. to melt a ton of glass, then the energy of an atomic bomb would run a medium sized glass-melting tank, making 70 tons of glass per day, for six months[2]. That is how much energy there is involved in the annihilation of one gram of matter.

We shall, however, probably get a better perspective on the subject, and a more balanced conception of the size of the bomb, if we compare it with natural phenomena with which we are thoroughly familiar, rather than by trying to visualize 20,000 tons of T.N.T. going off at once. Few, if any, of us ever expect to see that experiment, and it is describing the unknown in terms of the equally unknown. It seems to me better to describe the bomb in terms of the thunderstorm, for almost all of us have seen thunderstorms, and most of us see many of them every year. Moreover, the thunderstorm occupies a unique place in our minds: we never tire of it: we always admire it: we are not strictly enamored of it, but we rejoice at its magnificance, we regard it with a mixture of reverence and awe, we are normally both frightened and uplifted. Historically, for Aryan and Semite alike, the thunderstorm is the physical embodiment of the Lord of Heaven, the clothing and panoply of the chiefest of the Gods.

The winged bulls of Assyria are graven images of the thundercloud, and the cherubs that guarded the ark of the covenant are the same thing. For a cherub is not a fat-bellied baby on inadequate wings: it is a towering creature on gigantic pinions, with a voice of thunder, and dealing death by lightning. Thus the two cherubs that guarded the ark of the covenant stood fifteen feet high and had each a wing-spread of fifteen feet, and the sacrilegious sons of Aaron perished by lightning at their hands.

And this perhaps also is the riddle of the Sphinx, half god, half lion, a graven image of the thundergod, in a land that scarcely knows a thundercloud.

The ten commandments were uttered in a voice of thunder on Sinai and engraved upon stone by the lightning, while a terrified encampment of Israel cowered in the valley below; and perhaps the golden calf that Aaron, or Jeroboam, made, would have been a winged bull if gold had been sufficient to model the grown animal. It was not till the time of Elijah that the still small voice replaced the thunderstorm as the voice of God.

[1] $E = mc^2$, where E is energy in ergs equivalent to a mass of m grams and c is the velocity of light $= 3 \times 10^{10}$ cm/sec.
[2] 1 B.T.U. = 252 calories = approximately 10^{10} ergs.

About the time that Moses communed with the thunder-god on Sinai, the Aryans were pouring through Khyber Pass into India. There they settled the vast plains of Indus and Ganges, with the Himalaya towering on their north. There the terrifying display of Sinai was multiplied a million fold for in all terrestrial creation there is no such display of might as comes each year on that climatic day when Indra wheels his massed artillery against those stupendous ramparts and the monsoon breaks upon the roof of the world.

Greece and Rome concurred in this, that the chief of the gods is he who wields the thunder. Jupiter is not the oldest of the gods: Saturn is older. But Jupiter Tonans, the thunderer, is president of the host of Olympus: to him the other gods, and goddesses, must ultimately appeal, and ultimately submit. Vulcan may sometimes stage a good show with Vesuvius or Stromboli, but he is but a lame god, a comic opera god, of whom even his wife is a little ashamed. But she does not take the thundergod lightly.

We may see in all this the working of the basic primitive human mind: we see it in savages in ancient cultures, and in modern ones. Psychologically it is no doubt based on the fact that a tiny child, savage or civilized, is afraid of only two things, and one of them is a sudden loud noise; and the greatest of such noises is the thunderclap. In this respect, all religions have their final psychological bases in a primitive and basic instinct.

We may now turn to the physics, rather than the psychology, of thunderstorms.

To evaporate a gram of water at ordinary atmospheric temperatures requires 600 calories or 2.5×10^{10} ergs. Conversely, when a thunderstorm precipitates liquid rain from invisible vapor, it releases 2.5×10^{10} ergs for every gram of water precipitated.

We measure rainfall in inches of precipitation, and many a thunderstorm lays down more than an inch of rain. Sometimes it does not take it many minutes to do so.

Now if an inch of rain falls over an area of a square mile, the number of grams of water is easily calculated, and from this we can compute the energy released. It comes out as 1.5×10^{21} ergs. This is equivalent roughly to one atomic bomb, perhaps nearly equal to two.

Now the area thoroughly devastated by an atomic bomb is probably at least a square mile, so we do not need to drop such bombs in a pattern closer than one to a square mile. In such a pattern they would be equivalent, in energy released, to an average good thunderstorm.

There are differences, of course. Most of us would prefer the thunderstorm to a bombing on such a basis. We have a healthy respect for Jupiter Pluvius, even Tonans, but our respect for the Manhattan District is the respect we accord to the devil. Well-named is Plutonium, the material of the god of the underworld.

One principal difference between the storm and the bomb is the fact that the storm normally releases most of its energy in the upper air, where we earth-bound creatures encounter little of it. Another is the fact that the energy of the storm is released more uniformly over the area, and has no centers of intensity comparable with that in the immediate neighborhood of the bomb explosion. The storm does not lay down a poisonous pall of radioactive fission products, slow-enveloping, insidious and sinister shroud of death. Finally, though, the storm may release more energy than the bomb, it takes considerably longer to do it, minutes at least, in place of seconds or fractions of a second.

These are differences, and important differences; but the similarity in total energy, per square mile, of the bomb and the storm, is our point at the moment.

The annual rainfall at Bikini Lagoon is not yet known. It seems reasonable to suppose it may be quite similar to that at Ujelang, also in the Marshall Islands. Here the rainfall averages about 83 inches per annum, and as much as 11.7 inches has been recorded in a 24-hour period.[3] Bikini Lagoon is about twenty miles long and averages ten miles wide from north to south. Its area is therefore about 200 square miles. With a rainfall of eighty inches or more per annum, it follows that the rain is equivalent, in energy released, to some 15,000 or 20,000 atomic bombs per annum, or an average of fifty atomic bombs a day—one every half hour, the year round. Such is the scale on which nature works at Bikini, and such the scale on which Admiral Blandy and Joint Task Force One operated. King Juda[4] should be glad that Jove looses his bolts upstairs, and not where Blandy placed his.

What then must be the scale of operations when Indra assaults the thousand mile chain of the Himalaya?

The energy received by the earth from the sun, at the top of the atmosphere, amounts to about 1.9 calories per minute for every square centimeter of area. This figure is known as the "Solar Constant." The disc of the earth, 8,000 miles in diameter, has an area of 1.27×10^{18} square centimeters.[5] The energy received by the whole earth per minute is therefore 10^{26} ergs, or the equivalent of 100,000 bombs per minute.

This is Jove's ultimate arsenal, from which he manufactures his lightning bolts. This is the source of the fire and fury that blasts from the muzzles of Indra's levelled guns from Kashmir to Assam. From this stock, too, the nameless gods of the Andes draw their power, and send the floods of the Solimoes each year to swamp the vast Selvas of the Amazon, earth's greatest river system. Here, also, are replenished the black clouds shadowing with wings the land beyond the rivers of Ethiopia, sending their waters to the rainless vale of Egypt from sources known of old only to the Sphinx, whose enigmatical smile is perhaps that of the god of the storm-cloud, knowing more than mortals about these things.

The Sphinx is smiling perhaps at the big bad bombs of Bikini, for he knows what a real arsenal is like.

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[3] Sailing Directions for the Pacific Islands, Vol. I, p. 575. U. S. Hydrographic Office, #165 (1938).
[4] Chief of the Bikini natives.
[5] This is the cross section of the earth, of course, not the surface of the earth: πr^2, not $4\pi r^2$.

• Robert F. Walker, formerly with the Owens-Illinois Glass Company's Streator, Illinois, plant, has been transferred to the company's plant in Gas City, Indiana. Mr. Walker is acting in the capacity of supervising industrial engineer. He worked at the Alton and Streator plants for thirteen years, and succeeds John Arnsman who will now work on new mechanical developments.