U. S. SERVICE SERIES

THE BOY WITH THE U. S. RADIO

By

FRANCIS ROLT-WHEELER

With Sixty-Five Illustrations
From Photographs

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The Boy With the U. S. Radio

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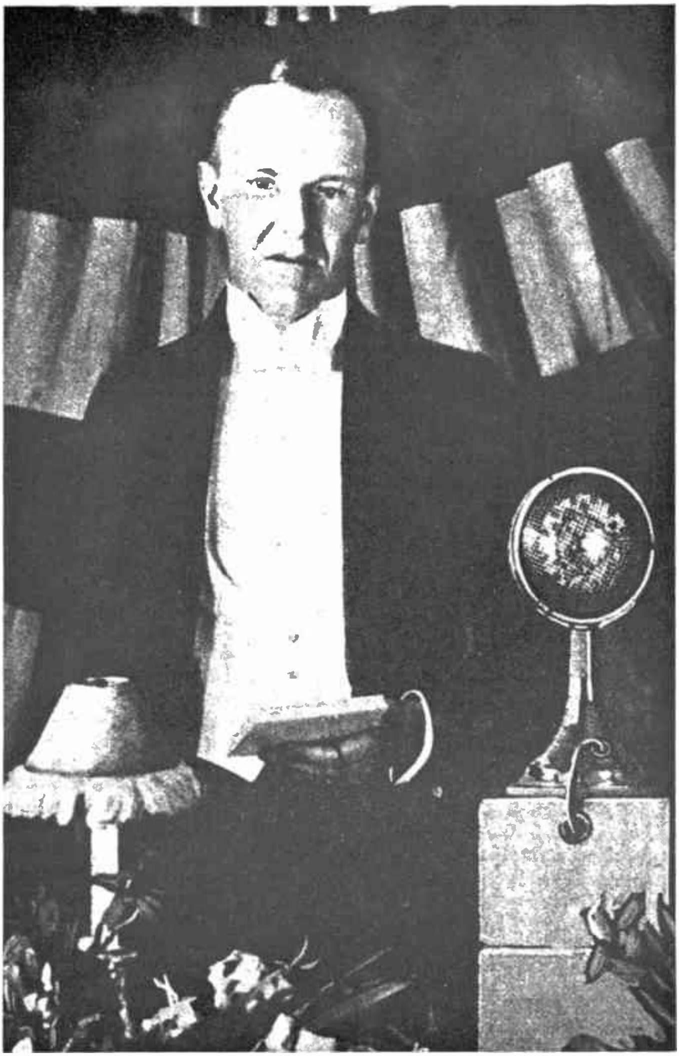

THE PRESIDENT OF THE UNITED STATES USING RADIO.
President Coolidge delivering the 1924 Lincoln's Birthday address.
Over five million listeners-in, from the Atlantic to the Pacific,
heard his speech.

FOREWORD

The author takes this opportunity of expressing his appreciation of the valuable assistance received from the officials of the United States Government, especially in the Signal Corps of the U. S. Army, the Radio Service of the U. S. Navy, and in several branches of the Department of Agriculture and the Department of the Interior. Special thanks are also due to the *Radio News*, the *Q S T* (organ of the American Radio Relay League), and to the *Literary Digest*. For courtesy and advice, the author is indebted to Marconi's Wireless Telegraph, Ltd., and to the Radio Corporation of America, as well as to numerous book and magazine publishers who have granted the right to use copyright illustrations and material.

A further word may be said. This book, while it endeavors to treat of the history, theory, and methods of radio in a simple but accurate manner, is deliberately intended to be neither theoretical, technical, nor constructional, for, in each of these fields, there are plenty of books written by men of the highest standing in the radio profession. In this volume will be found neither mathematics, engineering technique, nor advice in the building and management of wireless sets.

The author does not regard radio as an end in itself, but as one of the latest of the many means provided whereby citizens of the United States may more fully realize the fullness of life, the mutual equity which makes for liberty, and the pursuit of happiness.

PREFACE

Carried as by the hands of genii in that most mysterious of all things—the ether—radio waves have given the world a new thrill and a tremendous urge for progress. Giant forces speed invisibly to the most distant corners of the earth—corners of thousand-leagued boots ready to spring to service at the bidding of any one who holds the "Open Sesame."

There is a splendor and a wonder in wireless which sets the pulses leaping. Mystery and adventure lurk in the receiver of a radio set as nowhere else in the world, for no one knows what the unseen will bring. Experimenters have crossed the threshold into a wonder-world, and even broadcast listeners-in share in the reflected glory of their achievement.

America is in the very forefront of radio advance. The Government of the United States uses wireless to a greater extent than any other government in the world. Whalers in the Arctic and tramp steamers in the tropics benefit alike; storms, floods, and fires are heralded by wireless warnings; radio beacons stud the land as lighthouses the shore, farmers from coast to coast are in daily contact with crop affairs, education is sent by radio to settlements where there is no school, and invisible ministers preach in long-closed churches.

To show what radio really is and what it has done, to reveal a little of its mystery and show what still remains unknown behind, and to portray the evolution of the life of an American community through the use of wireless is the aim and purpose of

THE AUTHOR.

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This last statement was not without its effect. Many "cove families," as they are called, who live mostly in isolated coves or creek valleys of the Southern Alleghanies, are descendants of Cavaliers of good family who emigrated from England during the times of the Puritan Commonwealth. As a rule, such families hold tenaciously to everything which reminds them of past gentlehood, and, in many rude cabins in Tennessee, Western Virginia, and the hill-counties of North Carolina, heirlooms and treasures may be found which date back to the seventeenth or even to the sixteenth century.

The Cecils of Ants'-Hole Creek could trace their ancestry to Lord Burghley Cecil, Queen Elizabeth's prime minister, although, in their present state, they were not much above the "poor whites" in their standard of living.

They had their treasures, too. "Great-grandfather's Book"—an ancient manuscript volume bound in vellum, written by a remote ancestor—was their chief reminder of old-time pride and glory, although the boy Hugh was the only member of the family for several generations who had taken an interest in its pages. His father, who bore the historic name of Burlingame—or "Burly"—Cecil, had never even learned to read.

THE BOY WITH THE U. S. RADIO

CHAPTER I

THE LIGHTNING-MAKER

"HAVE you got any silk, Ma?"

"Silk? What for, Hugh?"

"To make lightnin' with, Ma."

Mrs. Cecil, better known among her mountain neighbors as "Old Lady Cecil," looked up dully from her sewing. She was well enough used to Hugh's queer ways, but this request seemed especially absurd.

What should a boy want with silk?

As for the reason given, that seemed to her more ridiculous, still.

"I'd sooner yo' be hoein' the corn-patch 'n wastin' time over such nonsense!"

"I finished the hoein' yesterday, Ma. An' it isn't nonsense, neither! I *can* make lightnin' out o' silk an' a bit o' glass. Great-grandfather's Book says so!"

This last statement was not without its effect. Many "cove families," as they are called, who live mostly in isolated coves or creek valleys of the Southern Alleghanies, are descendants of Cavaliers of good family who emigrated from England during the times of the Puritan Commonwealth. As a rule, such families hold tenaciously to everything which reminds them of past gentlehood, and, in many rude cabins in Tennessee, Western Virginia, and the hill-counties of North Carolina, heirlooms and treasures may be found which date back to the seventeenth or even to the sixteenth century.

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"Yo're right sure the hoein's done?" "Old Lady Cecil" queried dubiously.

"Sure, Ma!"

The mere statement was enough. A boy from a "cove family" might be lazy and shiftless, he might even be degenerate as well as ignorant, but he would neither lie nor steal.

Mrs. Cecil rose languidly. She was a gawky figure in her faded cotton wrapper and sunbonnet, which latter rarely left her head, even in the house; her slouching walk, as she crossed the room, would have revealed to any keen observer the mental dullness characteristic of her type. Yet a certain poise of the head, and the delicate shaping of the hands —albeit roughened by work—spoke of good breeding many generations back.

She opened the squeaking drawer of a home-made bureau and came back with a square of bright-colored material, which she handed to Hugh.

"It's right sure silk, is it, Ma?" he queried, anxiously.

"A bit of your father's mother's weddin'-gown," came the answer, in a drawling, toneless voice; "I've kept it for quilt-piecin'. It's old an' oughter be good. They hadn't conjured to make shams in those days."

Hugh nodded an understanding of his mother's scorn. The same bitter hatred of shoddy modernity was in his veins, too. To the boy's mountain mind, commercial trickery for the sake of making money was nothing more nor less than stealing. His father had told him often enough that, while a man-slayer might, on occasion, be regarded as a friend—especially if the slaying had taken place as the result of a vendetta or a mountain feud—a thief was something even below contempt. Just now, however, Hugh was too full of his own ideas to want to talk.

"If it's right silk, that's fine! Thanks, Ma. You see what I do with this!"

Mrs. Cecil scarcely heeded. Her interest in anything was hard to waken, harder to retain. She went back to her sewing, a task never ended, for her brain, hereditarily weakened by generations of marriage of cousins and even closer inbreeding, could not concentrate for more than a few minutes at a time. Half the day she sat with her hands folded in her lap, the mind in a state of vacancy.

Hugh's temperament was very different. His was one of those cases occasionally to be found in cove families, wherein, as a result of atavism, or reversion to original stock, a child is born with the abilities of his ancestors but with a brain which seems to date back centuries ago. The phenomenon is not rare, as the history of the "poor whites" shows; of late years many a man has risen to eminence in the South in spite of his cove upbringing, and such men owe their intellectual powers to a reversal to ancestral culture.

"Dad," said Hugh, as he passed his father, who was sitting in his accustomed position on an upturned keg close beside the door, his rifle, as always, across his knees, "I'm goin' off to the stead to make lightnin'."

The statement was a mere matter of form, but Burly Cecil had made it a rule that his son must always tell what he was going to do. Not that the father had any intention to interfere, but family feeling was strong, and the mountaineer dimly realized that the necessity of being forced to reveal future plans would keep Hugh out of serious mischief.

The "stead" (an old seventeenth century word for a building, which lingers in the word "homestead") was a small, low-roofed log cabin which Hugh and his elder brother had built, years ago, when playing at "feuds." The two boys had amused themselves in making this structure as strong as a blockhouse fort, and they had deflected a mountain rill down a rough chute which passed through a corner of the stead and gave them water.

The death of his brother had thrown Hugh a good deal on his own resources, and a certain primitive mechanical instinct which he possessed had led him to spend some of his lonely spare time in making rough models of such machines as his slender experience had enabled him to see.

Thus, using for power the considerable body of water which came rushing down the chute, he had rigged up an overshot water-wheel by nailing empty tin cans to the rim of an old buggy-wheel which had lost its tire and half its spokes. With this water-wheel, he drove a small circular saw and a tiny grinding-wheel. These were the only two machines that Hugh had ever seen in operation, and he had copied them in miniature as best he could. The saw, indeed, was too rickety for practical efficiency, but the lad had succeeded in cracking corn and wheat for family use in his little mill.

Once, at Foljambeville, the nearest town, the boy had seen an automobile standing outside the frowzy, unpainted frame building which called itself a "hotel." As the hood of the machine had been raised, in order to allow the engine to cool, Hugh had examined the mechanism as closely as he could.

"Rotary motion—that's what you call 'going-round driving power'—can be changed into reciprocal motion—or 'end-for-end'—very easily. Lots of machines do it.

"All you've got to do is to fasten a rod with two loose joints to a revolving wheel, anywhere off centre, and the rod is bound to go up and down. It can't help it. To keep the rod from dangling all over the map, make the bottom end go up and down in a round box or pipe. Then you have the whole arrangement!"

On his return from Foljambeville, Hugh had put this newly-acquired mechanical knowledge into practice. In one of the spokes of his buggy-wheel, half-way between the hub and the rim, he had burned a small hole with a red-hot wire; he was forced to burn it, for he owned neither gimlet, auger, nor brace-and-bit. Into this hole he had glued firmly a hardwood plug, six inches long, with an eye in the free end. This made a rough "eccentric," though the boy did not know the word.

Next, following the suggestion which the automobile owner had given him, Hugh had peeled and trimmed a long, straight sapling, and burned a hole in each end. This done, he had tied the rod by its top hole to the eye in the plug, making the knot a

The owner, returning from dinner, on seeing the boy's bewildered interest, had briefly explained the mechanics of a gas-engine as simply as he could. The man's intention had been kindly, but even this rudimentary explanation had been far, far too difficult for Hugh to understand. Half the words had no meaning for the mountain boy.

Only two things had actually got into his head.

The first was that some kind of a "contraption," called an "electric spark," exploded gas and drove something which made the machine go. This the boy was able to understand, because he knew that it was the explosion of powder in the barrel of a rifle which made the bullet go.

The second thing which he had grasped, fitted into his mechanical ideas. This was that an up-and-down motion—he had understood the plan of the piston—could be transformed into a circular motion, and that the latter force turned something which revolved the automobile wheels. He wondered if this change of motion could be made to work the other way.

"Mister," he had asked, "can any kind o' goin'-round drivin' power be fixed so as to work end-for-end?"

"Sure!" the automobile owner had replied.

stituted that he always wanted to get a practical result.

It had taken him several days of hard thinking to decide that, if he wanted to use his up-and-down power, he must make a connection direct to the piston itself, for the sapling connecting-rod was too limber and frail. That, he came to see, meant two things: first, that there must be a slit in the cylinder, so that a plug driven into the piston could go up and down freely; second, the cylinder must be heavy or solidly braced, so that it would be stable enough to resist the sidewise pull on the piston.

This was amazingly clear mechanical thinking for an absolutely untrained mind, such as that of Hugh.

If the boy could have got a perfectly new piece of stove-pipe, and have cut a slit an inch wide in it for two-thirds its length, leaving strips at top and bottom to hold the pipe together, his troubles would have been solved. But he had no money to buy materials, and his request to use a piece of the kitchen stove-pipe had been curtly refused. Therefore, he had been forced to make a substitute for himself.

He had taken a square five-gallon kerosene-can, of which there were several lying around the place. In one side he had cut out an inch-wide slit, leaving loose one, so that the rod should have a little play. There was his "crank-shaft."

The automobile owner had spoken of two loose joints, and, by dint of cudgelling his brain to try to remember the mechanical explanation he had heard, Hugh had figured out for himself that the bottom end of the rod must be fastened to what he called —having forgotten the right name—a "blob." To make this, he had sawed a round stick of fire-wood so as to leave an unsawn part in the centre, and, then, a couple of inches farther out, had cut it through. A few blows with the axe, used as a chisel, had given him a short round block with a lug in the centre. Through this lug he had burned a hole, by which he fastened the "blob" to the bottom hole of the rod. Thus he had made his rough but workable "piston."

The cylinder had been a more difficult problem. A bit of rusty stove-pipe had served as his first apparatus, and, though this fell to pieces after the first few up-and-down strokes of the piston, it had shown him that he was on the right track. In addition to the frailty of the material, the stove-pipe had another disadvantage. It did not allow any method whereby Hugh could turn to use his up-and-down machine, and the boy's mind was so constrips at top and bottom, to hold the can together. Next he had taken three empty tomato-cans, cleanly cut off the top of one and the tops and bottoms of the two others. Then he had cut notches in the rim of the can which still had its bottom and in the rim of one of the others, after which he had bent the strips of tin between these notches inwards and outwards alternately to form grooves, into which he had fitted the straight rims of the two cans. When the grooves had been pinched back, and hammered firm, Hugh found himself the possessor of a smooth cylinder made from the three tomato-cans.

He had then cut a slit in this cylinder corresponding in length and width to the slit in the square can, had put the cylinder in and against the side of the kerosene-can so that the slits juxtaposed, and had filled the intervening space with earth, tamped down hard. This braced the cylinder solidly all round, as far as the slit. Thus, the tomato-cans could not move sidewise, because of the tamped earth, and they could not slide down one over the other, because they fitted into notches. Here, then, was a solid cylinder, for the weight of the earth held it rigid.

Putting the piston in this cylinder, Hugh had then propped up the kerosene-can on stones, directly under the crank-shaft, until the piston, at its lowest descent, nearly, but not quite, touched the bottom of the cylinder. Then he had fastened two bits of wood, parallel-wise, over the top of the can, holding down the cylinder, but leaving space for the crank-shaft to pass through. This was to prevent the tomato-cans being pulled apart by the upward stroke of the piston.

So much done, Hugh had started the water-wheel. Sure enough, as the wheel revolved, the piston, driven by the eccentric of the crank-shaft, moved up and down the cylinder with a steady stroke. It rattled a good deal, but it did the trick. The rotary action of his water-wheel had been transformed into the reciprocal motion of a piston.

In order to satisfy the lad, there had been still something to be done. The piston must be made to do work. Hugh had planned this, while he was busy with the earlier operations. Through the slit of the kerosene-can and cylinder, he had driven a plug into the piston, which projected outside the cylinder. To this plug he had fastened a rigid connecting-rod, and thus had a reciprocating machine at his disposition. By a later improvement he adapted this from a perpendicular to a horizontal movement.

Mechanically, the boy's ideas were good, though crude. Considering that he had no knowledge, no guide, no books, and no appliances, that he was practically discovering for himself and by himself every device he used, Hugh's achievement was extraordinary. In his log-built stead the mountain boy was groping alone along the paths of mechanical experiment which humanity had taken centuries to traverse. But he did not have to discover the principle. That had been given him in his brief talk with the automobile owner.

Hugh's machines worked, indeed, but they did little more. The loose connections of twine and the whittled wooden parts caused a friction and loss of power which made it barely possible for his piston even to operate a butter-churn. Later, however, these devices were to prove of incalculable value to him, not only because the making of them had taught him to think, and to translate his ideas into practical efficiency, but, even considered as machines, they were to have an influence in shaping his career.

The boy had turned to full advantage one of the two mechanical suggestions which had been given him by the automobile owner at Foljambeville. But the other part of the explanation—that of the "electric spark"—evaded him completely. Pondering this idea gave no result; he had no mental foothold.

In answer to repeated questions, his father had told him that electricity was the same thing as lightning. The mountaineer was unable to explain clearly; he knew nothing farther.

Hugh had puzzled a good deal over this statement, while hoeing corn, picking off potato-bugs, sawing wood, or tramping over the mountains with the old muzzle-loading shotgun. He asked himself continually if he could not harness the lightning spark, just as he had harnessed the mountain stream. The man with the automobile had set this "electric spark" to work, why could not he? But he did not know how, and to pull down the lightning from the sky seemed as impossible as to throw a lasso over the moon.

Almost a year after his single visit to Foljambeville, there had come that famous winter when the long-abandoned schoolhouse on Ants'-Hole Creek had once more boasted a teacher. She was an old maid, scrawny, untrained, and inefficient, but none the less, from her Hugh had learned to read. Unhappily for the boy, the county was too poor to pay a teacher's salary for more than two months in the year, and Hugh had not advanced much farther than a mere spelling-out of the harder words when the term came to an end. The following year the crops had been poor, and so there had been no school.

Hugh had got a fair start, however. He had obtained the supreme advantage of being able to read enough to continue by himself. Slowly, and with difficulty, he puzzled out the meanings of the words as best he could, using, for his text, the only books available. It had meant hard work, but, all the more, what he read had remained fixed in his mind.

There were but two books in the possession of the family. One of these was an original edition of the "Demonology and Witchcraft," of King James I, which was treasured as a sacred Cavalier relic; the other was the historic "Great-grandfather's Book." The latter had been written, not exactly by Hugh's great-grandfather, but by an ancestor, Roger Cecil, the pioneer founder of the American branch of the family, who had come to Virginia in 1652.

This book, which was entitled "New Theoriques of Objeckts," proved to be the deciding factor in Hugh's life. It was written in faded ink on much-yellowed paper, and contained a strange mixture of mediæval physics and alchemical superstitions, together with some shrewd comments on the principles of scientific experimentation.

A large part of the book consisted of a translation into seventeenth century English of the first section of William Gilbert's "*De Magnete, Magneticisque Corporibus*," the book which has caused Gilbert to be known as "The Father of Electricity," and which was published in Latin in 1600. This portion was followed by long quotations from Gellibrand's "*Discourse Mathematicall on the Magneticall Needle*," published in 1635. Most of this part of his ancestor's manuscript was incomprehensible to Hugh, for he knew no more of mathematics than the multiplication table up to "six times."

The second part of the book consisted mainly of a record of conversations between the author and his intimate friend Robert Boyle, who, after the Restoration of the Stuarts, became the leading scientist of his time, author of several books on electricity and chemistry, and the founder of the Royal Society. Included therein was a letter from Boyle, written in Magdeburg, where he had visited Otto von Guericke, who, some years later, became famous as the inventor of the air-pump; this letter told of von Guericke's early experiments in physics and gave Boyle's own comments on them.

From some of the paragraphs at the end of the book, it seemed evident that Hugh's ancestor had been engaged in carrying out some secret researches in magnetism and electricity when the English Civil War broke out between the Cavaliers and Roundheads. Immediately, the amateur scientist had dropped his experimentation, drawn sword, and fought for the king.

His kinsman, the second Earl of Salisbury, described by a contemporary as "a man of no words save for hunting and hawking," had ignobly deserted Charles I when the royal cause began to weaken, turned traitor, and had sold his cousin to the enemy in order to curry favor with Cromwell. Roger Cecil managed to escape capture by the Roundheads and fled to America. There, the hardships of a pioneer life had left him no time for science, and only his manuscript remained to tell of his researches.

The king's treatise on witchcraft and "Great-grandfather's Book" constituted Hugh's whole library. During the two years following his short term at school he had conned them over and over again: firstly, in order to learn to read fluently; secondly, in order to master what they contained; and, finally, to study how he could turn the information to practical use.

The witchcraft treatise he speedily set aside as containing nothing directly useful. The boy's mind fed more and more on the electrical and magnetical information in his ancestor's book. He could repeat word for word every scientific statement therein contained, even to the mathematical paragraphs that he could not understand.

Curiously enough, during those two years, it had never occurred to Hugh to do any experimentation along those lines. Machines—such as the sawmill and the grinding-mill—he had seen in action, and it was natural enough to copy them, but, so far, "electricity" and "magnetism" were only words in an old book.

A hasty speech from his father had been the unexpected means of starting the boy on the path of experiment.

A few days prior to Hugh's request to his mother for the piece of silk, Burly Cecil had come into the house after an unsuccessful day of hunting, wet through, and out of temper. Seeing the boy reading, as usual, by the log fire, the father had said, harshly:

"What are yo' breakin' yo' neck over that book fo'? How d' yo' know what it says is true? Tell me that!"

Taken aback, Hugh hesitated for a moment, and then declared proudly:

"Because Great-grandfather was a Cecil, an' couldn't lie!"

The mountaineer made no immediate answer. Several hours later, as his manner was, he resumed the conversation as though there had been no time interval between, and responded:

"He might ha' been wrong, though!"

He tapped the ashes from his pipe on the rough pine table as he spoke.

Like all his neighbors, Burly Cecil usually smoked his home-grown tobacco in a corn-cob pipe. He always did so when out-of-doors, but he also possessed a pipe which he used only in the house. This pipe was of briar-root, with an amber mouthpiece. It belonged to the days, eighteen years before, when Burly Cecil had been a well-paid lumberjack, and had gone courting Hugh's mother.

The boy was nettled by this reflection on "Great-grandfather's Book," and was stung with a sudden desire to prove that what he read was true. If this, his only source of knowledge, should fail him, what would be left?

His eye caught the yellow sheen in his father's hand as the mountaineer tapped the tobacco-ash out on the table. Like a flash, a word recurred to him:

"Amber!"

He leaned forward eagerly.

"Isn't that amber on your pipe, Dad?"

"Reckon so," came the slow answer. "That's what the store man said."

A phrase from the historic book came back to Hugh's memory. It ran:

"If that a piece of this most deluctable amber be rubbed with vigour on the face of a woollen cloth . . ."

"Dad," he queried, "isn't your coat made of wool?"

"Yo'r ma carded the wool, spun it, an' wove it. She'd say so."

Hugh's breath deserted him in sudden excitement.

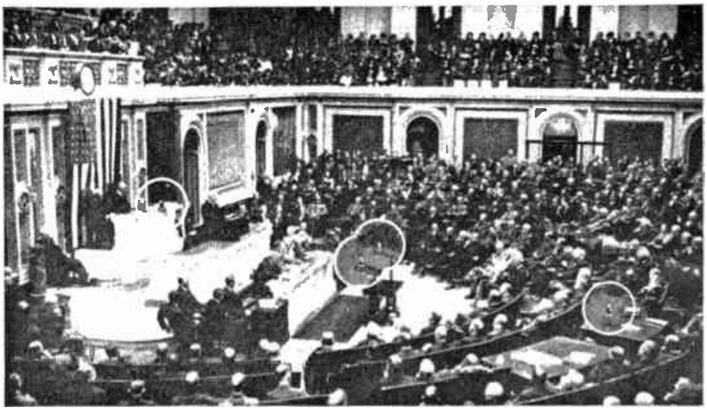
"Rub the amber on your sleeve, Dad! Rub it hard!"

"What fo', boy?"

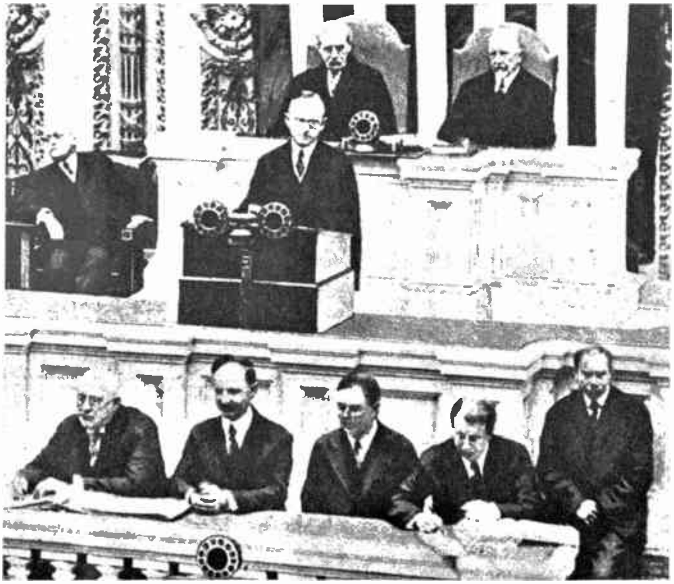
"Rub it, Dad! Rub it!"

With a shrug of indifference, the mountaineer gave the mouthpiece a few sharp rubs on his coat-sleeve.

"Now, Dad! Put the amber close to that to-



THE FIRST PRESIDENTIAL MESSAGE EVER SENT OUT BY WIRELESS.
President Harding delivering his message to Congress, Dec. 8, 1922. The microphones (outlined in white circles) picked up the words and transmitted them to the U. S. Navy broadcasting station.



Courtesy of Radio News.

THE FIRST PRESIDENTIAL MESSAGE HEARD INSTANTANEOUSLY FROM COAST TO COAST.
President Coolidge addressing the 68th Congress, these four principal microphones enabling citizens in every State in the Union to hear the words of the Chief Executive of the nation.

TALKING FROM NEW YORK.

Courtesy of Radio News.

HEARING IN LONDON.

Radio-Telephone across the Atlantic, using the regular telephone wires on land, thus enabling office-to-office communication across the ocean.

bacco-ash on the table, an' see if anything happens!"

The boy could hear his own heart thumping as his father, with a final rub, stretched out his hand and presented the mouthpiece of his old pipe to the light flecks of gray ash.

They leaped to the amber as though they were alive.

"I'll be tarred!" the mountaineer exclaimed.

He tried it again and again. Each time the ashes danced.

Wild with delight at this success, Hugh rushed off and returned in a few seconds with a down feather which he had pulled out of a pillow.

"Rub again and try with this, Dad!"

A moment's friction of the mouthpiece sufficed. Not only was the feather readily attracted to the amber, but, when the mouthpiece was lifted, the fluff actually hung suspended to it for more than a minute. A thin piece of paper, torn from a mail-order catalogue, behaved in the same way.

"It's just like the book says! You see, Dad! It's all true!"

In spite of his slow-moving brain, the mountaineer was impressed by the result of this experiment, described by his ancestor nearly three centuries before.

He was sufficiently interested to try to find out from Hugh just what it was that made the feather hang to the amber.

But Science had not advanced so far in those early days as to be able to assign causes; all the information that "Great-grandfather's Book" could give was that, although amber (*elektron*, in Greek) was the first substance observed to possess attracting or "clutching" qualities, it was not the only "electrica," as the ancient Greeks had supposed. The old volume affirmed that there were many other "harpy" substances, which would attract light objects, when rubbed.

Hugh's ancestor, moreover, had been more interested in magnetism than in electricity, even as his predecessor, the great Gilbert, had been. Neither one nor the other had the slightest idea that these two states of matter might be merely differing forms of the same force. It was the discovery of the parallelism of magnetic and electrical phenomena which led to the development of telegraphy, of telephony, and finally of wireless, the latest wonder of Science to be turned to practical use.

By the morning following the experiment with the amber mouthpiece and the tobacco-ash, the mountaineer's interest in the subject had died down, but

Hugh had lain awake nearly all the night, puzzling over the causes of the strange and surprising things that he had seen.

Dawn found him fevered with excitement. The success of his first experiment had set the boy on edge with eagerness to try everything mentioned in the old manuscript book.

He would have given anything to own a magnet, of which so much was written therein, but he had no idea that such a thing could be bought, nor would he have had the money to buy it, if he had known. Later, he was to learn how to make a magnet, but that time had not come yet. He had contented himself, at first, with repeating the experiments of the amber rubbed on a piece of flannel picking up ash and down-feathers, just as in Ancient Troy, three thousand years ago, the Trojan spinning-women were annoyed by the fluff which clung to their amber spindles.

"Great-grandfather's Book," however, carrying forward Gilbert's researches, made the significant remark that the "clutching" power must be a physical property and not merely an attribute of amber, since other things were also "electrica."

Referring to such substances, the ancient author said:

"A solid rod of fair glass, well rubbed with silken stuff from the silkworm of China, begets this clinging property in many objects. Nay, more, if thereafter the knuckle be approached thereto, it is said that a spark may be seen. . . ."

Now, "a rod of fair glass" was not likely to be found around a frame shack in a mountain cove. Therefore, it must be made. Hugh had noticed that bits of broken glass ran together in the heat of a big camp-fire. That meant that glass could be melted. He had decided to try to make a glass rod.

After a dozen failures, by the heat of a charcoal fire he had succeeded in melting down some pieces of finely broken glass which he had put in a clay mould. This had meant a couple of weeks' work, for the boy had been forced to prepare the charcoal himself, and to repair a decrepit pair of bellows of which the skin was half rotted away and the valve lost.

When completed, his rod was scarcely "fair glass." It was dirty in hue, opaque instead of transparent, incompletely fused, and far from straight. The boy was hopeful that it would serve his purpose, just the same.

Rereading the passage concerning the knuckle-spark, Hugh had noted that the suggestion had come from the famous Otto von Guericke, who (in

1663) was the first man to construct a frictional electrical machine.

This machine consisted of a globe of sulphur, turned by a winch, and it was electrically excited by the application of the experimenter's hands, previously well warmed at a stove.

Hugh's ancestor, in his comment on von Guericke's suggestion, advanced the idea that a glass ball or a disc might take the place of the sulphur globe. As a matter of fact, precisely this experiment was carried out twenty years later by the great English philosopher and scientist, Sir Isaac Newton, and the success of the glass disc led to the construction of several types of powerful frictional machines, such as those of Ramsden (1768) and Nairne (1787).

The boy's experiments with the amber mouthpiece had convinced him that everything to be found in his ancestor's book was true. Fortunately for him, however, his seventeenth century guide had warned him against over-confidence in scientific discovery. The boy's ancestor had learned prudence from Gilbert—that wise old thinker of the days of Queen Elizabeth—who, as long ago as 1588, had written the following words:

" It is very easy for men of acute intellect, apart from experiment and practice, to slip and err.

. . . Nought (in this book, the *De Magnete*) hath been herein set down which hath not been explored and many times performed and repeated, and that not by other but by my proper hands. . . . Let none believe from overmuch credulity, for there be many figments and falsehoods, which, in the earliest times, no less than nowadays, used to be put forth by raw smatterers and copyists, to be swallowed of men."

Gilbert had cited many of the crude superstitions of his time with regard to magnetism, such as that the lodestone lost its power when rubbed with garlic, or that magnets prepared under certain planetary influences attracted fish to nets, that occult charms added to magnetic powers would reveal hidden treasures, that the lodestone would open any lock when used with magic words, and that the rust of magnetic filings in water made a powerful love potion.

"Though it requireth not great powers to determine that such tales be unlikely to be true," wrote the old scientist, "yet, even so, nowhere have I proclaimed them to be false save when I have put forth their falsity by experiment and test."

Thus advised against hasty conclusions, and yet taking his ancestor's book as a scientific gospel, Hugh prepared himself to test the suggestion that a "rod of fair glass, well rubbed with silk of China" would become possessed of enough electricity to produce a spark. In his own crude speech, the boy wanted "to make lightning," and, armed with the silk that his mother had given him, it was in these words that he announced his intention to his father.

Much to the lad's surprise, the mountaineer lumbered to his feet, and, throwing his rifle over his shoulder, responded briefly:

"Reckon I'll go along."

This remark evinced a most amazing interest on the part of Hugh's father, for he had not visited the stead more than half a dozen times in three years, and he regarded Hugh's models as nothing more than childish toys. The fact that the proposed experiment was based on "Great-grandfather's Book," however, gave it a serious character in the eyes of the mountaineer.

This time. the models in the stead took on a greater importance for him. The success of the trial with the amber mouthpiece had dignified all Hugh's former efforts. Somewhere, back in the mountaineer's slow brain, arose a feeling that perhaps his son might turn out differently from the other mountain boys.

Hugh's hopes had led his father to expect something sensational in the making of lightning. In this, Burly Cecil was doomed to disappointment.

The glass rod, when rubbed hard with the silk, became electrified, it was true. It attracted straws, feathers, bits of paper, small cylinders of dry pith, tobacco-ash, and numerous other light objects, even better than the amber mouthpiece had done. But, rub as hard as he could, Hugh could not produce a sign of a spark.

The boy's disappointment was greater still. He was not only anxious to attain his goal for his own sake, but especially he wanted to make a brilliant showing before his father. He knew that, unless he made good, it would be difficult to awaken his father's interest a second time.

Among the light objects which Hugh had used to test the attractivity of the silk-rubbed glass rod was a small cylinder of pith taken from the inside of a dry twig. It was not quite spherical, but nearly so.

While the boy, in desperation, was frantically rubbing the glass, the mountaineer, who was smoking, idly rubbed the amber mouthpiece on his sleeve, as he had done in the experiment of a few days before, and presented it to the pith. The little cylinder rolled after the amber as if bewitched. Yet, a moment before, it had been pushed away by the glass rod.

Here was something strange!

The man slowly revolved in his mind what this action of the pith could mean. Presently he said:

"I'm thinkin', Hugh, thar's queer doin's here."

"What, Dad?"

"Wa'al, when yo' put yonder glass to yon bit o' pith, it first pulled it to, an' then pushed it off, didn't it?"

"Yes."

"An' yo' said it looked like one dose o' the rod was enough to sicken anything it touched, so that, afterward, it kep' away instead o' comin' to?"

"It looked like it, Dad."

"Wa'al, when I put my pipe to yon pith, just now, instead o' pushin' it off, it pulled it to."

"It did?"

"Try it yo'rself!"

Surprised and puzzled, the boy repeated the experiment, again and again.

There was no doubt of it. The pith ball, when electrified by the amber, was pushed away, or repelled by it, when approached a second time; yet it flew to the silk-rubbed glass rod. Once electrified by the glass, the pith showed the same repulsion to it a second time, yet was attracted by the amber.

"Looks like thar was two kinds o' 'lectricity, Hugh!"

"It sure does!"

"The table's kind o' rough," went on the mountaineer, "an' keeps the pith from rollin' easy. Maybe if yo' could hang it to somethin', we'd see clearer yet."

Though amazed at the interest shown by his father, Hugh made no comment. As a matter of fact, the mountaineer was inwardly very proud at having preceded his son in noticing that the amber and the glass produced different kinds of electricity. It was, practically, the first discovery of his life.

A stick stuck into a crack in the wall made the necessary bracket, and then Hugh felt in all his pockets for a bit of string. He had nothing finer than binder twine, quite useless for so small a thing as the ball of pith. Noting that the piece of silk was a trifle unravelled, the boy pulled off a silk thread from it, knotted the end, made a hole through the pith with the needle he had been using for his experiments, threaded the pith and hung it up.

With this swinging pith, quickly responsive to any influence, father and son came to realize more clearly than ever that there must really be two kinds of electricity. Hugh promptly called them "glass" and "amber."

In this, the two experimenters in their log cabin were unconsciously repeating independently the discoveries of du Fay, a French physicist, who (in 1733) was the first to announce the theory of "two electric fluids." He called these: "vitreous" (or glassy), and "resinous" (amber is a fossilized resin).

Before he went to bed that night, Hugh had thoroughly learned for himself that objects charged with vitreous electricity (now called positive +) repel objects similarly charged, that those charged with resinous electricity (now called negative —) also repel their likes, while objects charged with the opposite kinds of electricity attract each other.

Almost every American boy knows this first rule of electrical science: "Unlikes attract, likes repel." Hugh, in his mountain home, had to find it out for himself. He would never have been able to do so, if his ancestor's book had not set him on the track.

"It's right interestin'," admitted the mountaineer, as the two went to the house for the characteristic cove meal of "corn-pone" and "fried hog-meat," "but yo're a long way from havin' made any lightnin'!"

"I'll make it yet, Dad!" the boy responded, sturdily.

He tried to lie awake that night, considering the results of the day's experiments, but his eyes closed in spite of him. His first waking thoughts were of his new discovery.

The boy saw clearly enough that he could excite or generate electricity, either with the flannel-rubbed amber, or with the silk-rubbed glass. That was easy.

Now, the book had said that a spark could be got from a revolving globe of sulphur, and might be got from a whirling glass disc. Since he had no sulphur, the first was out of the question. Certainly, friction on a whirling glass disc ought to give more power than merely rubbing a glass rod, but it was the same thing in principle. Was it not likely, therefore, Hugh thought, that the amount of electricity which he had been able to generate was strong enough to attract a ball of pith, but not strong enough to make a spark? If so, his principle was right, but his process did not produce the necessary electrical energy.

Hugh was not clever, but his isolated life gave him so few interests that he was able to concentrate thoroughly on this problem. Every scrap of his mental energy focussed on this point.

Presently, he came to realize that the difference between rubbing a glass rod and whirling a glass disc was only a mechanical difference. So far as that went, by means of his water-wheel, he had the mechanical power. The difficulty was to adjust his machine to this new kind of work.

The disc of glass was the first thing to be got. From an abandoned house up the creek he took a pane of glass about a foot square, and, with a good deal of trouble, managed to mount this on a wooden shaft, which he attached to the axis of his grinding-mill. The corners of the pane of glass were a good deal in his way, but he could not figure out any method to cut them off without cracking the glass. Quite obviously, there were no glass-cutting diamonds in a mountain home! He had to leave the corners.

Being afraid that, if his wheel revolved too quickly, it would cause the glass to fly to pieces—for, by reason of an accident which had happened recently in the local sawmill, the boy knew that high speeds will cause even a circular saw of high-grade steel to fly to pieces—he decided to reduce the power of his water-wheel. To accomplish this, he tied strips of stuff over the mouths of most of the cans (or cups) on the rim of his buggy-wheel, so that only a few of them functioned, causing the wheel to revolve slowly.

When he had connected up, and the pane of glass was in steady rotation, Hugh found that it was easy to secure electricity by pressing the revolving glass with the piece of silk. The strength of the attraction was certainly greater than that which he had secured by rubbing the rod. Still, it would not give a spark!

The boy experimented with the friction of a dozen different substances. Remembering von Guericke's globe of sulphur, he tried to excite the revolving window-pane by pressing lightly on it with his hands, well warmed. This worked well, though no better than the silk. Even so, there was no spark to be seen. What could be wrong?

Another week passed before he got a clue. Then the idea came to him that the various substances which he had found the best for rubbing purposes were all of animal origin: wool, which came from the sheep; silk, from the silkworm; fur, from a cat-skin; and the skin of his own hands. Leather, he thought, was another kind of skin; maybe it would work, too. He tried a piece of old boot, with increasing success.

Leather was only a kind of hide, that he knew. How about squirrel-skins? There were plenty of those about the place, for though 'coon-skins and 'possum-skins had a ready market—even rabbit-skins had a sale—squirrel-skins were too thin to make good fur.

Taking four good pelts, he nailed good-sized pieces from them on four blocks of wood, and fastened these blocks on a frame so that the revolving glass brushed between the two pairs, upper and under. This gave a steady friction. When the glass was at a fair rate of speed, Hugh put his knuckle to the glass and distinctly felt a tickling. He tried again and again, each time, his fingers tingled.

He was getting nearer, surely. But there was no spark, as yet. Why?

The boy tried to renew his father's interest in the problem, hoping to get some suggestions, but the mountaineer no longer wanted to trouble himself about it. Hugh had to figure it out, alone.

After a while, he decided that the electricity was wasting by being spread all over the glass pane. He stopped some of this by spreading the silk, like an apron, over the revolving disc by attaching one end to the rubber. This was not enough. The boy got a sneaking suspicion that the corners had something to do with it. Certainly, the old book spoke of a "globe" and a "disc," and neither of these had corners. Dimly Hugh realized that he must find out some way to collect or to concentrate this electricity to a certain point. The question was—how?

There was something else to be considered. Hugh began to ask himself whereabouts the electricity actually was. Could it be inside the glass, or was it on the surface?

Remembering that he had succeeded with many different rubbers or exciters—silk, flannel, leather, fur, and even the skin of the hand, remembering also that several substances had given him electricity when rubbed—glass, amber, sulphur, and hard rubber—the boy came to the conclusion that the electricity could not be actually in the glass, but must be on the surface. Perhaps, since a light object—such as the pith ball—was sensitive to the electric effect even before it was in contact, the electricity might be in the air just above and below the glass.

This was an extremely good guess (for magnetic fields *surround* a conductor carrying a current and electrification itself is merely the creation of a physical state in a surrounding dielectric, such as air), but it was just far enough from the truth to lead the boy all wrong. It led him to try to collect the supposedly electrified air by blowing it with a bellows. This was quite useless. No matter how hard he blew the bellows, the electrical effect did not seem to leave the immediate neighborhood of the glass.

This failure drove him back to his ancestor's book. Therein he reread a passage translated from Gilbert's "*De Magnete,*" in which the "Father of Electricity" described his making of a "versorium" (the earliest electroscope, an instrument for determining electrification). This consisted simply of a needle balanced on a pivot. Gilbert had used it for the purpose of showing that other substances, besides amber, could be electrified by friction.

Suddenly a query shot through the boy's brain:

Why had Gilbert chosen a needle to show the effects of electricity?

The answer came pat:

Because the old scientist had found that a metal needle is readily affected by electricity and keeps it for a long time. (Soft iron is easily magnetized by the electric current, but loses its magnetism as soon as the current stops; steel is less easily magnetized, but retains it. In all magneto-electric machinery, such as the dynamo, this fact is of prime importance.)

Could this steel needle be the clue he sought?

Hurrying back to the stead, Hugh set the glass pane revolving. Then, needle in hand, he gradually came closer and closer. Just before he touched the glass with the needle, he thought he heard a very faint crackle, and distinctly he felt the tingling in his fingers though his hand was the full length of the needle away from the glass.

The electricity, then, must have run down the needle! Surely this must be the way to success!

What could he find, of metal, bigger than a needle, but which would have points on which to collect the electricity?

The only thing which occurred to him was the garden rake, with which he had spent many weary hours in the vegetable patch.

Hugh made the hundred yards to the garden patch in nearly record time. Returning with the rake—which, fortunately for his experiment, chanced to be bone dry—he cleaned it carefully and propped it up by its wooden handle so that the teeth nearly, but not quite, touched the glass plate. He threw the coupling in, and the wheel commenced to revolve.

A moment Hugh waited, and then, more hopefully than ever, he brought his knuckle near to the iron end of the rake. His hand was still a quarter of an inch from the metal, when, with a sharp crackle, a spark leaped across.

The boy burst out of the stead in wild excitement, and, seeing his father sitting on his accustomed keg, he shouted in triumph:

"Come, Dad! Come quick! I've done it! I've made lightnin'!"

CHAPTER II

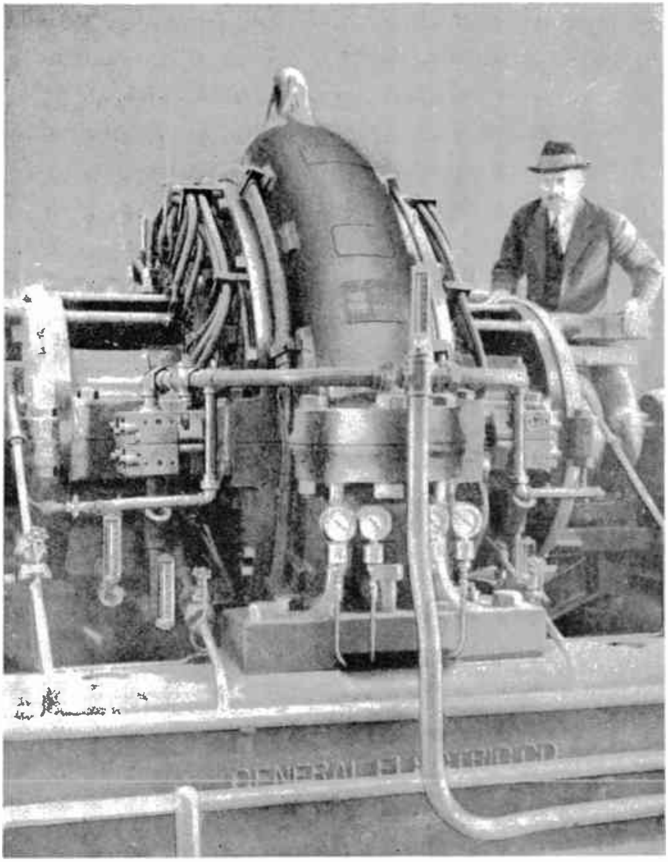
AN ELECTRIC DOCTOR

Hugh's discoveries, though in themselves of slight importance, electrically considered, were destined to have a marvellous effect on the life of Ants'-Hole Creek. In this change, his father was to take a deciding part.

Prior to this time, Burly Cecil had occupied himself very little with the affairs of his neighbors and had never paid any attention to what might be called the community life of the cove. He was, by preference, a solitary being, and took no notice of local politics.

When, in previous years, such questions as school or improved roads came up for consideration before the electors, Cecil had always voted against them. He had never learned to read, and saw no special reason why any mountaineer should do so; he had no use for towns, and opposed everything which threatened the isolation and independence of cove life.

Now, however, he took the other tack. "Great-



Courtesy of General Electric Co.

THE MOST MARVELLOUS ELECTRICAL MACHINE IN EXISTENCE.

The Alexanderson high-frequency alternator, capable of 200,000 cycles a second. It is used by the U.S. Government high-power trans-oceanic stations, for sending out long-distance messages with a wave-length of fourteen miles, at 22,000 cycles. In other words, it can send 22,000 waves a second into the air, each wave measuring fourteen miles from crest to crest. Mr. Alexanderson, the inventor, is seen standing behind the machine.

A WATCH WHICH IS ALWAYS RIGHT.
Radio-controlled watch devised by Lieutenant J. H. Iseman of the Naval Air Service, which automatically receives the wireless time signals sent out daily, and corrects itself.

grandfather's Book" assumed in his eyes an almost magical importance. Hugh's ability to read it gave the father an exaggerated idea of the boy's cleverness. On the rare occasions when he met his neighbors, the formerly silent mountaineer talked freely of his boy's accomplishments with the lightning.

Some of the neighbors were ready to ridicule these experiments, but they did so cautiously, for Burly Cecil was known to be extremely touchy on questions of honor and never stirred a furlong from his house without his rifle in hand. In regions where an incautious word was apt to start a feud that might run for generations and cost a score of lives—like the Hargis-Cockrill feud in Kentucky—people were careful as to what they said.

There were many of the neighbors, however, in whom credulity was stronger than disbelief, who were ready to believe any wonder that was shown them, and, even, to make a thing seem even more astonishing by exaggerated recital. Hugh's simple experiments, as retold by some of these wonder-seekers, took on marvellous proportions, and it was small surprise that many curious people were attracted to the Cecil homestead. In consequence, Hugh had to repeat his experiments many times during the following autumn. Each day he became more and more adept, and he steadily improved his crude frictional electrical machine by better working parts and smoother adjustments. The garden rake gave place to a comb made from steel pins, and a diamond ring, worn by a caller, gave him the means to cut off the corners of his plate and to make it a real disc.

These demonstrations were not always smooth sailing, however. Many of the visitors, misled by the fantastic tales which they had heard, demanded impossibilities, such as asking Hugh to split a piece of wood with his electric spark, because, they said, "Lightning splits trees." Others of the neighbors, of a jealous temperament, resented the interest aroused, and declared that "the Cecils gave themselves uppish airs."

Among the latter were the Iretons, a family of Puritans who had emigrated to Virginia when the Cavaliers were restored to power, and who, therefore, had a centuries'-old grudge against the Cecils. A feud would have been started long before, no doubt, but that the Iretons had been a sober, religious family for generations, though the old Puritan strain in them was steadily dying out.

Sandy Ireton still retained some of the sturdy virtues of the stock, but he had married his own grandfather's Book" assumed in his eyes an almost magical importance. Hugh's ability to read it gave the father an exaggerated idea of the boy's cleverness. On the rare occasions when he met his neighbors, the formerly silent mountaineer talked freely of his boy's accomplishments with the lightning.

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Sandy Ireton still retained some of the sturdy virtues of the stock, but he had married his own niece, an unintelligent girl with a pretty face, and his three boys all bore the stamp of degeneracy. Cram Ireton, the eldest, a hulking youth of eighteen, had a forbidding countenance and was of a vicious disposition; Ollie, aged sixteen, was feeble-witted; Will, the youngest, who was only a year older than Hugh Cecil, while a clever lad, was afflicted with fits, and possessed an ungovernable spirit of ugly mischief.

One afternoon, a group of curiosity-hunters came up to the Cecil homestead, " to see lightning made," as they expressed it. Among them were the three Ireton boys. Hugh, little pleased by their coming and thoroughly uneasy at their presence, went and called his father. He even refused to open the stead until the mountaineer was there. This evidence that they were mistrusted did not improve the tempers of the Ireton boys.

Hugh had set the water-wheel in motion, and the pane of glass was revolving swiftly when Will Ireton, who was standing with his back to the frictional machine and was looking out of the window, as though accidentally let his shotgun slip from his shoulder, so that the barrel fell full on one of the squirrel-hide pads which acted as an upper rubber on the revolving disc. An inch to one side or the other, and the glass pane would have been smashed, wrecking all Hugh's work.

Will Ireton half turned with an expectant grin, waiting to hear the crash of the glass, but, before he had fully turned round, he felt himself lifted clear from the ground by his shock of hair and by the waistband of his trousers, and carried bodily out of the stead.

It was no use for him to squirm in that grip!

A couple of seconds later, his head was under the overflow of the water chute and he was drenched to the skin. Not till then did the mountaineer let go.

"Think yo'self lucky that yo'r gun didn't break anything," said he. "It's more'n a sousin' yo'd have got!"

"It was an accident-like," spluttered Will, indignant but frightened.

"Accidents o' that kind don't go here," came the grim answer, "or, if they do, worse accidents follow! An' thar's no room on my land for a liar. Make yo'self scarce!"

The two brothers had hurried out, and Cram, the eldest, held his shotgun in both hands, suspiciously ready. Burly Cecil eyed him closely.

"Yo're likely to have trouble wi' that gun, if yo' don't know how to hold it," he remarked. "I'd hate to have to teach yo'!"

Cram Ireton tried to face him down, but moral weakness gives a shifty eye. Unable to meet the mountaineer's stern gaze, he sulkily put his gun on his shoulder.

"Father'll hear o' this, Burly Cecil!" he said, menacingly.

"An' if he's got sense, he'll hammer the three o' yo' first an' then tell yo' to keep away from hyar. I'm no friend o' your father's, an' he knows it, but he's a better man, ten times over, than any o' his boys'll ever be, an' yo' can take that to yo'selves. Now, git!"

With grumbled threats which they did not dare to make loud enough to reach the mountaineer's hearing, the three louts left hurriedly.

"Do you suppose they'll try shootin', Dad?" queried Hugh, for he knew how readily mountain blood seeks revenge for an insult.

"The boys might, fo' they're a bad lot. Yo'd better keep yo' eye skinned an' yo' rifle handy. But, most like, Ireton'll come down to find out the truth. He don't like lyin' any more'n I do."

Burly Cecil was not wrong in his estimate of Sandy Ireton's character. The very next morning, shortly after sunrise, the descendant of the old Puritans came striding down to the Cecil shack. The mountaineer got up from his keg to greet him. After all, even among tacit enemies, hospitality is sacred.

"Will yo' have a drop o' the stuff, Sandy Ireton?" he asked, at once. Needless to say "prohibition" has not had the slightest effect on the making of moonshine whisky in the coves.

"After a bit, maybe," answered the visitor. It would be a mortal insult to refuse outright, and he had no desire to accept. "What I come fo', Burly Cecil, was to ask yo' about my Will. He says yo' gave him a duckin' yesterday."

"He's tellin' truth, fo' once. I did."

"Don't yo' reckon I can handle my own boys without another man interferin'?"

"I'm not sayin' what I think about yo'r boys! But yo' wa'n't thar yesterday, Sandy Ireton. Yo'd ha' done the same as I did, if yo' had bin. I'll show yo' how it was. Yo' come wi' me an' I'll tell yo' all about it."

He took his caller to the stead, and made Hugh start his frictional machine and produce the electric spark. Ireton was evidently a good deal interested and would have liked to ask questions about the machine, but he restrained himself, and uttered no word of approval.

After the experiment was made, Burly Cecil explained exactly Will's trick in trying to smash the revolving pane of glass.

"An' he didn't do it openly, but wi' his back turned," the mountaineer concluded. "That's dirty work, Sandy Ireton, like settin' fire to a man's corn when it's ripe an' he's asleep."

There is no crime more deeply loathed than this, in the coves, where a man's corn-patch is his whole livelihood.

Sandy Ireton spat thoughtfully on the ground.

"I'll give him a lickin' myself, when I get back," he responded, "but boys is hard to handle, nowadays."

This was equivalent to a full apology, and was the nearest approach to a friendly remark that had passed between an Ireton and a Cecil for generations.

Hugh's father, not to be outdone in courtesy, seized the occasion.

"Yo're one o' the school trustees, a'n't yo'?" he queried, knowing that education was one of Ireton's beliefs, a thing not strange in view of the fact that the latter was one of the three men, in the whole valley, who knew how to read and write.

"Reckon I hold over in office. It don't mean much, hyar. Thar a'n't been an election fo' two years."

"I've bin thinkin' about that. Crops is good. How about havin' a school-teacher this winter, an' openin' up the school ag'in?"

"Why," said Ireton, in surprise, "yo've allers been agin it."

"I'm for it, now."

"On account o' yon contraption?"

He jerked his head contemptuously at Hugh's frictional machine, although, at heart, he really admired it.

"Maybe. It a'n't for my own schoolin', that's sure," the mountaineer retorted, tartly. "Teachin' might do yo'r boys good, Sandy Ireton!"

This remark bordered on the hostile, and Burly Cecil regretted the words the minute they were uttered. He hastened to repair the bad effect, and continued:

"It'll do all the children good. Thar's five others in the cove what'll pay the school tax."

Ireton, whose expression had darkened at the rebuff, looked fixedly at his neighbor, but accepted the restatement.

"As fo' me," he said, "I've allers voted for schoolcate-looking, and, though plainly dressed, was attractive and even pretty.

Cram Ireton nudged his brother.

"Get that fluffy hair!" he said. "I've heard tell that gals wi' fluffy hair'll come to a dance like a dog to a whistle!"

Ollie Ireton grinned.

"Me an' Will'll run the school, I reckon!"

Hugh overheard. The blood rushed to his head, and, had he been alone, he would have risked a punch at Ollie. But Burly Cecil had heard the boys, too, and, since his father made no sign other than to compress his lips, Hugh very sensibly kept quiet.

Miss Ferguson leaped out of the buggy lightly. Every one was strange to her, except the three trustees, and she felt the atmosphere to be critical and even prepared to be hostile. None the less, she showed no timidity.

Ireton commenced to introduce her, in a rough way, to some of the waiting parents, but the girl stopped him with a gesture. She eyed the children, instead.

"Who'll ring the bell for me?"

Half a dozen boys lurched forward, Hugh among them.

"in teachin', same as in hog-breedin'. A little of a good thing's a smart sight better'n a lot of bad, to my way o' thinkin'. But thar's some sense in what yo' say, Burke. We don't need to pay fo' fixin's our children can't learn."

Ireton had a conscientious streak and would have deprived himself in order to have a good teacher, but he knew that the people of Ants'-Hole Creek were actually too poor to pay much for school taxes. As the choice of a teacher was left entirely to him, he felt that he must try to meet the wishes of the other dwellers in the cove, or there would be no chance of school in succeeding winters.

The corn was in and shucked, the sorghum ripened, and syrup made before Ireton announced the date for the opening of school. No one, as yet, had seen the teacher save the three trustees, but it was known that she was coming for a term of ten weeks. This showed that her rate of pay was low, for the total sum which the county could afford to pay that year was only $140.

It was in Ireton's buggy that the teacher drove up, the first day of school. All the children were gathered at the schoolhouse, as well as most of the parents. A gasp of astonishment went up at the sight of the new arrival. She was small and delitered the mountaineer, looking after the retreating figure.

The sign was a sure one that Ireton had no desire to establish friendship.

Despite the known mutual hostility of the two strongest men in the valley, the impetus for a school appointment had been given. When it became spread in the cove that both Cecil and Ireton were in favor of school, the rest of the settlers followed suit. Public opinion, however, made it clear to the school trustees that they must engage the cheapest teacher they could get.

A lanky moonshiner named Burke, whose ability to read and write had been mainly directed to the finding out of ways to cheat the revenue officers, was the spokesman of the less-contented settlers.

"It a'n't as ef the kids hyar needed eddication, Sandy Ireton," he explained, "they don't! Every family owns its own land, an' thar's a plenty to go round. Yo' a'n't got no need to find a pedigreed teacher with all the fixin's. Catch a young un, if yo' can. She might stay three months instead o' two, fo' the same money. She'll board around, o' course. I'm willin' to take her fo' the first month, if yo' like."

"I'm fo' good stock, myself," Ireton answered, teachin', as yo' know. It's others what's keepin' everything back!"

The atmosphere was growing decidedly antagonistic. Both men knew it, and both were trying hard to keep themselves in hand. Burly Cecil kept back the retort which sprang to his lips.

After a moment, Ireton went on:

"Yo' say thar's six families ready to pay?"

Burly Cecil named them.

"I'll talk to the other trustees, then. As yo' say, crops is good. But ——" he hesitated, "it'll bring your Hugh an' my Will together, I'm warnin' yo'!"

"I've thought o' that. A bit o' fist-fightin' won't hurt either, as long as the fightin's fair," the mountaineer responded. "Whichever one gets licked'll learn to keep quiet. A youngster's got to find out how to take care o' himself, some time. My boy won't back down because o' yours, Sandy Ireton!"

"So!"

The exclamation was an agreement and a retort at the same time. Both men faced each other with levelled and lowered eyebrows.

"I'll go along, Burly Cecil, I reckon."

Turning on his heel, Sandy Ireton strode back down the creek.

"H'm! He didn't take a drink, after all!" mut-

"You do it," said she, nodding, and the lad hurried off.

Almost instantly, the cracked bell rang out its doleful peal.

"All of you please come in, all!" said the little teacher, authoritatively, and led the way into the schoolhouse. The rest, old and young, clattered in after her.

"Put two chairs here, one on each side of my desk!" she ordered, and asked Ireton and Burke to sit down.

Then she took her place, and very quietly, but no less definitely, gave every one present to understand that she intended to rule. She appealed to the sense of mountain honor in the children, and by a deft reference to "the responsibilities of men of education" turned the two trustees into necessary supporters of her position.

One of the boys started to whistle defiantly.

"Come here, you!" she rapped out.

The boy went on whistling, evidently quite ready to bring matters to an issue.

Ireton rose from his chair. One long stride took him to where the boy was sitting. With a jerk he brought him in front of the teacher's desk and left him there, then returned to his own chair. His meaning was clear. The teacher, herself, must manage the rebel.

Miss Ferguson got down. The boy looked at her with a curl of the lip, ready to give a saucy reply to anything she said, although keeping a wary eye on Ireton.

She said nothing.

With a quickness that the lad did not in the least expect, she dealt him a box on the ears, first on one side and then on the other.

"Now go and sit down!" said she.

The boy hesitated a moment, but, in his own home, he was accustomed to obey, and he did as he was told.

A hum of disapproval ran around the room. Several of the parents murmured openly. Mountain folk are sensitive, and this seemed to a good many people an infringement on the parents' sole right to punish.

Ireton caught the eye of his eldest son, and reading the evil look, his face grew dark.

The teacher returned to her desk, and with a final word to the parents, practically told them to go. When the room was almost cleared of the elders, she prepared to call the school to order.

"Reckon I'll stay a bit, Miss," suggested Ireton.

"Thanks, but I reckon not," she answered. "The children will behave."

"Yo'll find them wild!"

"That's why you need a school here."

The answer left little more to be said, and Ireton rose. He looked at the boys and girls, but principally at his own sons.

"I'm school trustee, I'll have yo' all remember," he said, incisively, "an' it's goin' to be right smart unhealthy fo' any one who makes trouble. Miss Ferguson, yo'll let me know if thar's anything wrong."

"If I can't handle the school, that will be my own fault, Mr. Ireton," she replied, "but I thank you, just the same."

"Very good!"

He walked to the door, looked back at the children, and strode out.

What amounted to a small riot broke out, as soon as the trustee left. The teacher went straight to the door, and several of the boys openly jeered at her, thinking that, in spite of her brave words, she was going to call Ireton back. But she locked the door and put the key in her pocket.

"Now," said she, as she got back to her desk, "let me thank you for this outbreak. Keep on a little longer! It gives me a chance to see at once which of you are honorable, and which, dishonorable."

The words fell like lead upon the more violent spirits there. To have been told to be "good," would have meant nothing to them; at the idea of "well-behaved," they would have laughed; but to be called "dishonorable," bit deep into the feelings of a mountain boy. Even the younger Iretons—Cram had gone out with the elders—quieted down. With one word, the teacher had got a grip on the school.

The rest of the morning was spent in examining the children, and, without hurting their touchy cove feelings, in making them realize how ignorant they were. When noon came, and school was dismissed, the new arrival had her charges well in hand.

And, as the children were leaving, she said, pointedly:

"Children who do not come to school will only show by their absence that they are afraid to come!"

This struck home, likewise, for "courage" is the second word of power in the mountains. Courage and honor govern the mind of the mountain boy, even as "cleverness" and "profit" have their appeal to the city-bred. Merely to tell a mountain lad that a certain thing "will pay" conveys absolutely no meaning to him.

The psychology of the cove and the city differ widely. The idea that education is of value because it enables a lad "to get on in the world" is a sentiment despised by mountain folk. Uninstructed as they are, they know enough to realize that an education which lowers child ideals to the sordid base of money-making, instead of raising them to higher levels, is considerably worse than none.

As the first couple of weeks of school passed by, it became evident to the cove dwellers that Ireton had chosen the teacher wisely. A mountain girl herself, she understood the character of the children, and her unflinching courage soon built up an admiring and a loyal following.

There was, however, a strong group of malcontents in the school, led by the Ireton boys, who resented the strictness of discipline. These fellows undertook to make life miserable for the teacher.

Beginning with mere schoolboy tricks, such as the bent pin or the string stretched across the schoolroom a few inches from the floor, they passed on to meaner and low-grade devices, such as smearing a mixture of glue and axle-grease on the teacher's desk and chair, to dirty her hands and ruin her dresses.

This last trick cost the Iretons dear. On discovery of the mess—but not before her apron had been badly soiled—Miss Ferguson called each child before her, examined their finger-nails and found some of the telltale mixture on both Ollie and Will Ireton.

Without showing any anger, she bade two of the older girls to go to the nearest house and bring back a tub, a pail of water and some soap. Then, amid the jeers of the other children, the two boys were forced to wash that apron in the presence of the whole school. Nothing could be more shameful in the eyes of a mountain boy, for " woman's work " is despised in the coves, where a man will not even carry a pail of water for the household.

This punishment led the Iretons to greater extremes. One day, from an overhanging tree, a bundle of thorns was dropped on the teacher's head as she was on her way to school, and her face was badly scratched. A couple of days after, the two boys took to shooting, from ambush, just to frighten the teacher, the bullets spattering the dust of the road a yard or so in front of her feet.

Yet never once did she appeal to Ireton or Burke, and the school trustees, though they were indirectly informed of these happenings, kept away from interference, just as the teacher herself had requested. Public sentiment, however, began to narrow down to a feeling that some drastic action must be taken, before the Ireton boys went too far.

From the very start, Miss Ferguson had taken an interest in Hugh, who worked hard at his simple lessons. The boy was intensely eager to speak to her of his scientific experiments, but a certain timidity held him back.

In the third week of the teacher's stay, however, she came to the Cecil home in her round of parental visits, and Burly Cecil took her to the stead and showed her the electrical machine.

Hugh operated it with great pride. The machine worked very smoothly, now, for the boy had improved it little by little, making a well-arranged double row of points instead of the crude comb which had replaced the garden rake, and had arranged a wire to the prime conductor which carried the squirrel-hide rubbers. From the points he could collect a positive charge, and from the rubbers a negative one.

The teacher examined the frictional machine with intense interest and put several questions to the boy which he could not answer. Her own questions, which were information-seeking, suggested that her knowledge of electricity was but small, and she made no pretense.

"I never finished high school, Mr. Cecil," she admitted frankly to the mountaineer. "Father died when I was in my second year there. That's why I had to start teaching, so soon. But I do know enough to see that this machine of Hugh's may be really useful. It seems to be just the sort of thing that Dr. Cameron was talking to me about, the other day."

"How's that, Miss Ferguson?"

"You know, perhaps, that Mrs. Burke, where I'm staying, is a sick woman?"

"She allers has bin, ever since I knew her. Folks say she has the jumps, can't sleep fo' more'n an hour at a time, an' wakes up screamin' wi' her skin twitchin' every which way."

"Yes, she's a good deal like that, and Dr. Cameron says that medicines don't do her any good. But he thinks electricity might help."

"Eh?"

"Just the day before yesterday he said to me he wished he had a medical coil, or even an electrostatic machine."

"Like this?"

"Something like this, I suppose."

Hugh broke in.

"Could I really do somethin' to help Mis' Burke?"

"You might! I don't quite know. Let me see again, Hugh."

The girl went over the mechanism, with puckered brows. It was evident that she was trying to remember her school lessons of physics and fitting those memories, as best she could, into the doctor's curt offhand remarks.

Hugh watched her, intently.

"Let me try that tingling feeling again, Hugh!"

Hopefully, the boy set the wheel in motion, and the teacher grasped the wires leading to the positive and negative poles of the machine.

"I don't know that the electric shock is strong enough to do much good," she said thoughtfully, "but, as weak as that, it certainly can't do any harm. And I know Mr. Burke is ready to try anything in the world which might help his wife. He is a good man in his home."

"Let him bring her hyar, then, Miss Ferguson," declared the mountaineer. "A'n't no harm tryin'!"

The girl examined the machine again, and then, hesitatingly, gave some simple suggestions based on her school reminiscences. She advised that the chair for the patient should be put on pieces of glass "to insulate it," though she admitted that she did not know what "insulation" was unless it were to prevent electric leakage.

"There's one thing sure, though," she announced, confidently, "and that is that electricity is a good deal used by up-to-date doctors, now."

Therein, the teacher was right.

Static electricity (such as Hugh's machine produced in feeble measure) is widely used for nerve diseases and affections of the skin; it has cured hysteria and done wonders in cases of functional paralysis. Faradism (with batteries of dry cells) has been found helpful in palsy and in weakness or emaciation after a long illness; it diminishes rickets in children. Galvanism (with direct current) is of vast benefit in muscle troubles, and the pains of sciatica frequently can be eased by this method. Electrolysis (which causes chemical changes in the fluids of the body and is so highly dangerous that only a thorough expert should employ it) produces amazing changes, acting favorably for kidney troubles and rheumatism, and even has checked malignant growths which were so far advanced that operation had become impossible. The X-rays and the effects of certain radio-active substances have developed a whole medical science of their own.

Every year brings into greater prominence this science of electro-therapeutics, or the use of electricity in the alleviation of pain or the cure of disease. But it demands extreme care and thorough scientific knowledge both of physiology and of electrical physics. Inexpert handling of powerful currents may easily produce disaster.

The following day, Burke drove up to the Cecil homestead with his wife. The woman was in a state of high nervousness, inclined to scream at any lurch of the buggy, which, on the unmade mountain road, rocked and pitched like a rowboat in a choppy sea. The teacher had come on foot, and had reached the house first.

Burke placed his wife in the chair, which had been insulated. Hugh put in one of the patient's hands an iron rod, and, in the other, a long wire which the teacher had brought with her and which ran out of the door of the stead and was fastened to a piece of metal lying at the bottom of the mountain stream. This "earthing" of the electricity was Miss Ferguson's suggestion.

Then, having coupled in the water-wheel, the boy brought the iron rod which the woman held to within a quarter of an inch of the points which collected the static electricity from the revolving glass disc. A spark flashed across, and the patient winced.

"Does it hurt, Jane?"

"It stings and tingles! No, it doesn't hurt."

A few minutes passed, the only sound in the stead being the rushing of the water down the chute, and the creaking of the wheel.

Burke, who had his fingers on his wife's wrist, feeling her pulse, nodded contentedly.

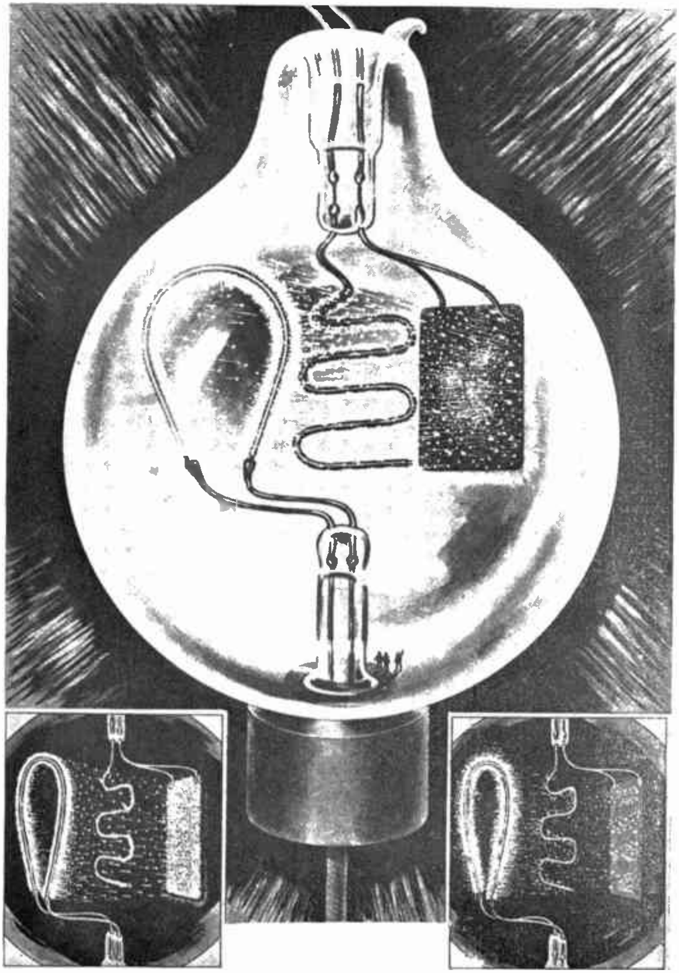
"It's a-gettin' more reg'lar!" he whispered.

The glass disc whirred on, pouring its weak electric charge into the woman's body. The effect was soothing. The nervous contractions of the forehead relaxed, the eyes closed, and the head drooped. Burke held her fingers tight on the iron rod. In ten minutes, she was asleep.

Tiptoeing across the floor, Hugh shut off the power, and the little log cabin became still.

For two hours the woman scarcely moved, sunk in a profound sleep, such a sleep as she had not known for many a weary year. Toward dusk, she stirred, and looked up at her husband.

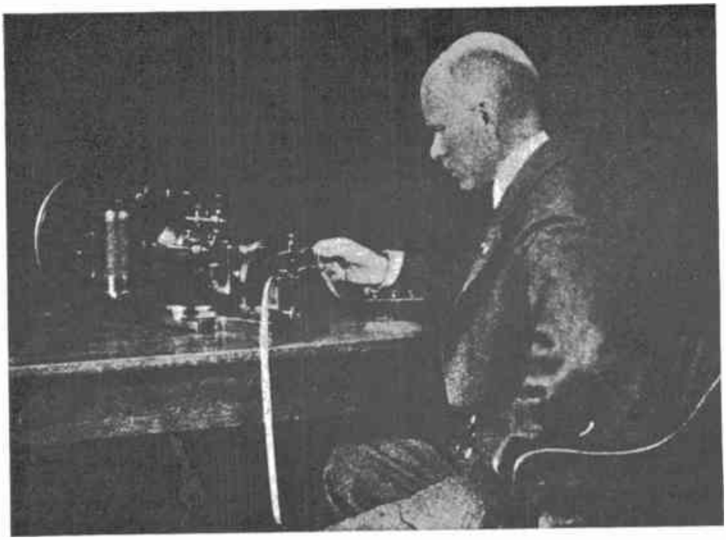
"I feel like I felt when I was a girl," said she, and drowsed off again.



Courtesy of Radio News.

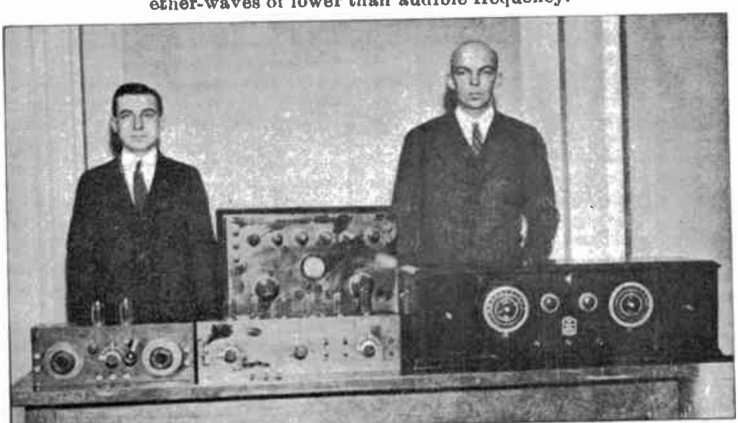
IF YOU WERE INSIDE AN ELECTRON TUBE.

Sketch made using the original De Forest three-electrode pattern. Proportionately the ions shown as passing from the filament to the plate should be several million times smaller. On the smaller picture at the left is shown what happens when the grid is positive; on the right, the condition when the grid is negative.



THE SILENT CODE.

Major-General Geo. O. Squier, Chief Signal Officer of the U. S. Army and a giant in radio progress, manipulating his invention for using ether-waves of lower than audible frequency.



Courtesy of Radio Broadcast.

THE SUPER-HETERODYNE.

Major Edwin H. Armstrong (at the right) originator of this all-important modern circuit. To the left is the first working model (1912); to the right, the perfected receiver (1924).

The moonshiner and the mountaineer exchanged glances.

"I'll carry her home," said Burke, softly. "She sha'n't be shaken to bits on that there road! Yo' bring the buggy."

"It's a goodish stretch to whar yo' live," the mountaineer reminded him.

The moonshiner stretched his lanky frame.

"I a'n't much of a man ef I can't tote her that far!"

He turned to the boy, but the words he wanted to say would not come. He gripped Hugh's hand and wrung it, as one man speaks dumbly to another.

Then, picking up the woman in his arms, he passed out of the stead and down the mountain road, picking his steps with care.

Burly Cecil put his hand on the boy's shoulder, with a movement of pride. Hugh looked up, and understood.

That was his chief reward.

CHAPTER III

DOWNING A ROUGH GANG

THE news of Mrs. Burke's improvement in health—for it was far from being a cure,—spread far and wide in the creek. The story of the "electric doctor-wheel" penetrated even to other valleys.

It put Hugh and his schemes in a new light before the neighbors. The "making of lightning" had been merely a curiosity to them, but the health-giving powers of the boy's revolving glass machine seemed something tangible.

People came to the Cecil homestead from all parts of the valley, begging the boy to cure them of everything from a sore finger to a toothache or heart disease. On Miss Ferguson's advice, Hugh responded to all such queries with the reply that he had tried to help Mrs. Burke only because Dr. Cameron had said that electricity would be good for her, and that he wouldn't dare use his machine on any one who was sick, unless a doctor had told him to do so. This very reasonable answer gave no offence, and caused people to think that the boy had a good fund of "horse sense."

About ten days after the sick woman's first visit to the stead, the teacher's month of "boarding out" with the Burkes came to an end. She was supposed to stay at the Iretons', next, but Burly Cecil had interposed, and had offered her such rough hospitality as was at his disposal.

For Miss Ferguson to have refused to stay at the Iretons, after the matter had been definitely arranged in advance, would, according to mountain standards, have been a gross insult, and the girl frankly confessed that she did not know how to get out of the invitation. Burke undertook to handle the somewhat ticklish matter, and set off at once.

"Sandy Ireton," he said, when the two men met, "yo've heard about my wife's gettin' better, a'n't yo'?"

"Thar's been some talk about it. Yo' mean wi' that Cecil boy's glass contraption?"

"That's it. Now, my wife, she cenjures to go ahead wi' that 'lectricity a while, seein' it's doin' her good, an' woman-like, she thinks she'd oughter have a woman 'round that shack, instead o' jest a boy. Mrs. Cecil, as yo' know, a'n't very bright. Now, ef the teacher was boardin' at the Cecils, this month, my wife'd feel easier in goin' thar."

Ireton looked his visitor straight in the eye.

"What yo're meanin' to say, Wat Burke, is that the girl don't want to come hyar! Tell yo' mind, an' tell it straight! Is she scared I can't keep order in my own house? Or is it that my house a'n't good enough for her?"

The moonshiner had no more fear of Ireton than he had of any other man. Defying revenue officers all one's life gives plenty of hardihood, and Burke returned the glance with equal sternness.

"Ef I thought so, I'd say so," he replied bluntly, "an' I wouldn' trouble to pick my words, neither. Yo' a'n't ever heard tell o' my bein' afraid to speak my mind! Since yo' put it that way, I'm not denyin' that I think the less any one has to do wi' those boys o' yours, the better fo' them, Sandy Ireton! But that a'n't what I come to say. About this question o' boardin' the teacher, I'm givin' yo' the wishes of a woman, an' a sick woman, at that."

Ireton gnawed his beard, as his manner was, when annoyed. He realized that Burke, in appealing to mountain chivalry, had put the matter so adroitly that he could hardly do otherwise than to agree to the moonshiner's request. But he knew, too, that the neighbors would interpret his acceptation differently, and this hurt his pride.

"Have it yo' own way, Wat Burke," he said, after an indecisive pause, "but I don't take it friendly o' yo'! "

"Take it what way yo' like. I'll say this, though, —I thank yo', for my wife's sake."

The very next day, Miss Ferguson moved to the Cecil home. The quarters were rough, for the only place for her was a draughty lean-to, where Hugh usually slept. Still, she was free from the fear of the younger Iretons. As for the boy, he moved a decrepit mattress to the stead, and slept on the floor, there.

As soon as the teacher was installed, she undertook a serious study of Hugh and his ambitions. The young teacher realized that this lad was by far the most promising of all her pupils, and believed that he ought to have a better future before him than cultivating the small and weed-infested corn-patch on the homestead. In order to get exactly the boy's viewpoint, she read the famous "Great-grandfather's Book," and followed, step by step, the mechanical and electrical experiments that the lad had made.

"What I've been wonderin' about most, Miss Ferguson," said Hugh, during the first of their long talks in the stead, "is, if there's any way o' storin' up electricity, like you can store molasses in a jug, or water in a jar?"

The last word struck the teacher's attention.

"A 'jar'! Wait a minute, Hugh, and let me think! A jar! A 'Leyden Jar'—yes, that's the word. What did I learn about that, when I was in school? Wait. Let me think!"

There was a silence of several minutes, while the girl ransacked her brain, and began to piece together the few lingering memories of her lessons in elementary physics.

"I can remember very little, Hugh," she resumed, thoughtfully, "but a few facts begin to come back. Yes, there is a way to store electricity.

"A long time ago, only a very few years after the experiments of von Guericke—which you've read about in your ancestor's book—von Kleist, dean of a cathedral in Pomerania, got the idea that it might be possible to electrify liquids as well as solids. He tried with water.

"He made a machine—something like yours, Hugh, only he used a globe of sulphur instead of a pane of glass—and secured his electricity that way. Then he took a thin glass jar, filled it half full of water, corked it, and drove a long nail through the cork so that it reached down into the water. This done, he touched the head of the nail to the collector of the frictional machine, so as to give a charge to the water.

"Then, holding the glass jar in one hand, he touched the head of the nail with a finger of the other hand, and received a sharp electric shock. This frightened him, for he hadn't expected anything of the kind, and he thought there must be imps in the jar. He never attempted it again."

"Couldn't we try that trick now?" interrupted Hugh.

"You might," she answered. "Probably an ordinary 'gem' jar would be good enough. While you're getting it, I'll try to remember some more of my old lessons."

The experiment proved to be of the simplest. The glass jar and a long nail were secured in a few minutes. It took the boy but little longer to whittle a closely-fitting stopper and to drive the nail through it.

As the frictional machine was working, the electric charge was almost immediately secured by holding the nail against the prime conductor. Following what he had heard, the boy then grasped the jar firmly with one hand and put a knuckle of the other hand to the nail. Immediately he had the delight of feeling a slight electric shock, though not enough to frighten him, as von Kleist had been frightened. Hugh found, too, that he could carry the charged jar as far away from the stead as he liked, and still get the same effect. This proved to him that some of the electricity from the frictional machine was stored in the jar.

The boy's experiment was but a repetition of von Kleist's historic experiment of 1745, which was repeated and carried out in much greater detail in 1746 by two professors in the University of Leyden, in Holland. These investigators improved the form of the jar, and discovered a way to increase its capacity of holding an electric charge. For this reason, this form of collector or " condenser " is still called a " Leyden Jar."

As Hugh was to find out later, this device—which is the basis of all modern condensers—is of the greatest importance in wireless. Indeed, radio could not have been developed without the use of the Leyden Jar. Even the most powerful of modern transmitting stations owe a large part of their successful operation to this experiment made by a Pomeranian priest, nearly two centuries ago.

As for Hugh, his achievement put him in a state of mingled delight and self-accusation.

"I'm a chump!" he declared. "That old chap didn't know any more about electricity than I do, an' he thought that trick out! Why didn't I think of it, myself? Just to put electricity into water an' have it stay in there, like sugar or salt!"

"Oh, but it doesn't, Hugh! That's not the idea, at all! Salt melts in the water and stays there in solution, but electricity is held largely by the glass. Modern Leyden Jars haven't any water in them!

"The one our class had, at school, was a bottle something like yours, but with much thinner glass. It was covered with tinfoil, two-thirds of the way up, inside and outside. The rest of the glass was varnished. There was a wooden stopper, through which passed a brass rod, with a knob at the top. The end of the rod, inside the bottle, was connected with three brass springs."

The boy pondered for a moment.

"What's the tinfoil for?"

"It has something to do with the collecting of the electricity, though it's a little hard to explain just how."

"An' the springs?"

"Oh, they're just so that the brass rod makes a good connection with the inner tinfoil. But one of the other classes had a Leyden Jar without any springs. The brass rod was attached to a chain, inside. The weight of the chain made it touch the inner tinfoil at several points and so made a good connection."

Hugh pondered.

"Do yo' reckon, Miss Ferguson, an iron wire through the cork would do instead of a brass rod?"

"It wouldn't be as good, but it might serve."

"I could make that, then. For the inside of the jar I'd cut off the top part of a tin can, slit it down, an' cut it nearly all round the bottom, trimmin' the bottom so's it'd go through the neck of the jar. Then, when I rolled up the tin, smaller, to go through the neck, when it got inside, the tin, bein' springy, would spring out an' fit the inside of the jar. The outside part's easy. That's just puttin' the jar into a tin that fits it tightly."

"You're certainly ingenious, Hugh, though I'm afraid you'll have an air space between the tin and the glass, instead of having the tinfoil glued on. But—go ahead and try!"

The job was a little troublesome, but the boy managed it, after a fashion. He even succeeded in fastening a brass knob from a metal bedstead to the galvanized wire which went through the wooden stopper. To the other end, inside the jar, he fastened a few links of a small chain, which rested on the bottom of the tin, itself connected to the side by the tongue of metal which the boy had not cut through.

Connecting the knob of the jar, thus completed, to the "points" of the frictional machine, he held it there for nearly ten minutes. Then, gripping the jar tightly in his left hand, he approached his right thumb to the brass knob.

There followed a screech that could be heard clear across the creek!

The jar fell to the ground and smashed, while Hugh jumped around the stead, holding his elbow and trying to rub his shoulder at the same time.

"Woof!" he exclaimed. "That was like the kick of a mule!"

"Are you hurt?" the teacher inquired, anxiously.

"N-no'm, I'm not hurt. I just sort o' got a scare." Then he grinned. "There were sure imps in that jar!"

His determination returned immediately.

"But I'll make another one, right away!"

This was not difficult. There were plenty of "gem" jars about the place, since the boy's mother, like other mountain women, made grape jelly from wild grapes every autumn. These were speedily emptied during the winter, and several of them were already empty. As for the tin linings and the rod and stopper, they were all ready to be fitted into another jar of the same size.

This time, however, Hugh was careful not to absorb the shock himself, all the more as the teacher had thought out a way of making the charge stronger.

Following this new plan, the boy wound a piece of wire around the outer tin, and left this wire trailing, so that it could not come near the brass knob. Then he charged the inner tin, negatively, by touching the brass knob to the negative pole of his frictional machine, the one which connected with the squirrel-skin rubbers. He further charged the outer tin, positively, by touching the wire to the positive pole of his machine, which connected with the collecting points.

In order to avoid getting the shock which he had suffered before, the boy made a pair of pincers from two slats of dry wood and glued bits of glass on their inside faces. Gripping in these pincers the wire which was connected to the outside tin, he brought it close to the brass knob.

With a snap and a crackle, a spark nearly an inch long broke across the gap of air that remained between the brass knob and the end of the wire held by the pincers.

"Woof! That's a real one!"

The boy's eyes were almost "sparking" themselves, in his excitement of discovery and accomplishment.

"It is big! Much bigger than I thought you could get," the teacher agreed. "You see, Hugh, you have succeeded in pouring electricity into a jar, just as you said you wanted to do, like molasses from a jug.

"But I don't suppose I ought to let you think of it like that, or you'll get the wrong idea. It's true that the electricity has poured from the machine. But it isn't held in the jug in a liquid mass, like molasses! Electricity is a force, rather than a thing. And that force has set up an electric push, or strain, between the inner tin and the outer one. This push is stopped, in some way, by the glass between. I can't exactly explain it, myself, for there's a lot which is too deep for me, but I can give you some idea of it, just the same.

"Do you remember, Hugh, how, in your first experiments with the amber mouthpiece and with the glass rod, you found out that substances with charges of the same kind repel each other?"

"Yes'm, I sure do."

"The same thing has happened in your Leyden Jar, though it isn't so easy to observe it as with your ball of pith. Let us see just what you did.

"First, you charged the inner tin negatively from the frictional machine. Since that gave the inner tin more electricity than it had before, that electricity must have come from somewhere. It came from the negative pole of the machine, and, therefore, left a lack at the opposite or positive pole.

"Next you connected the outer tin to the positive pole of the frictional machine. The drawing power of the machine, which had been robbed by the taking of the first charge, was so great that it pulled away all the electricity it could get from the outer tin, in order to try to even up.

"Then you took away the jar. Now, what state was it in? The inner tin had a lot of electricity, the outer tin didn't. There was, therefore, a big strain between the two, but the glass wouldn't let it go through. The glass itself was strained, because, since like repels like, the negative electricity in the glass was driven to the outer side of it, in order to get away as far as it could from the heavy charge of negative electricity on the inner tin.

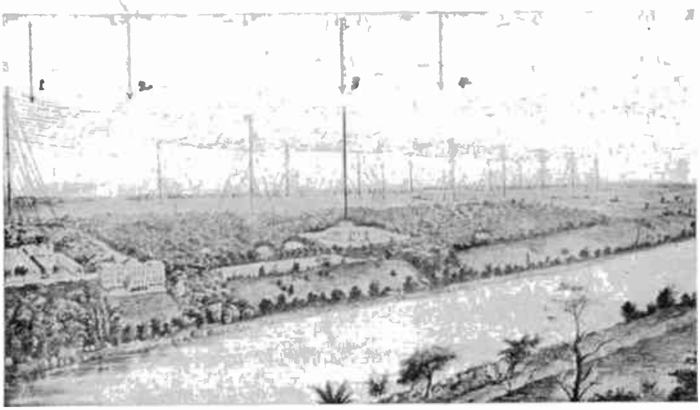
"After that, you brought the wire near the brass knob. This brought the overcharged tin and the undercharged tin almost into connection through the wire. When you did that, you made a path, or a circuit, which let the extra electricity in the inner tin go round to the outer tin, in order to even up the strain. What's more, it was in such a hurry to get there that it wouldn't wait until the metals actually touched, but jumped across the little gap of air which was in between, making a spark. Do you understand?"

Hugh nodded, but dubiously. The teacher, realizing that the boy was still confused, repeated her instruction over and over again, using simpler words and more illustrations each time, until at last he understood. The explanation, indeed, was as simplified as she could make it, and it went well enough with Hugh's scanty knowledge, though it could not be exact. It was surprising that the young teacher, only a meagerly educated mountain girl, had acquired the grasp of the subject that she really showed.

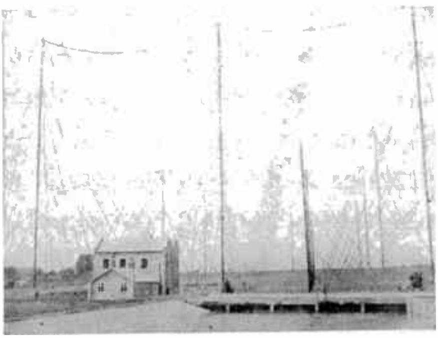
What actually had happened in that Leyden Jar, when the spark flashed across the air gap, was something that the girl teacher could not have explained accurately, even if she had been much older and very much better informed. The discovery of the real causes of electrical phenomena is a thing of very recent date, and these causes are not easy to make clear in simple terms.

A principal difficulty is that the true explanation deals with things excessively small. An example may help to show this. Take common salt. A grain of salt may be broken smaller and smaller until it is only 1/100,000th of an inch in diameter—which is the smallest particle that may be seen in a good microscope. Even so, it will still be a grain of salt. But one can go farther. If that microscopic grain of salt be melted in a drop of water, the salt will still be there, in solution, but even an ultra-microscope will not reveal the particles. Yet there must, at the very last, come a point at which this particle is the smallest that it can possibly be and still remain a grain of salt. This smallest bit possible is called a " molecule " of salt.

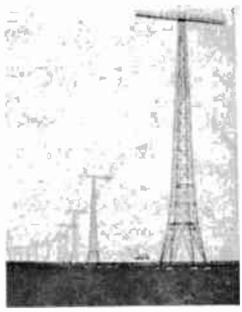
But salt itself, which is known chemically as sodium chloride or sodic chloride, is a compound of two other substances: a soft metal, sodium; and a green poisonous gas, named chlorine. Both of these are known as " elements," because they cannot be decomposed into other substances. The smallest possible quantity of an element is called an " atom." It must perforce be smaller than a molecule, since



The largest radio station in the world at St. Assise, France. Groups 1 and 2 are for accessory services, Group 3 is an 800 foot mast for continental traffic, Group 4 is an array of sixteen 800 foot masts for trans-oceanic traffic. La Tour alternators are used for transmission.

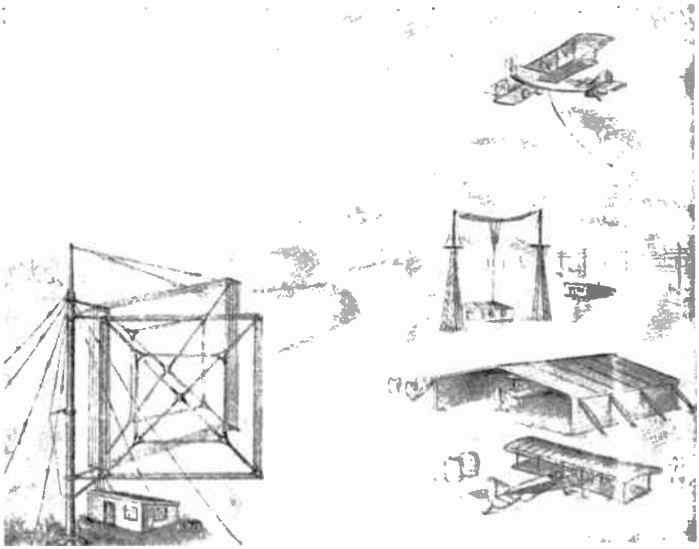


Part of the antennae at Seafield, England, used as a central radio-control station for India, Australia and all the most distant parts of the British empire. The arc system is used for transmission.

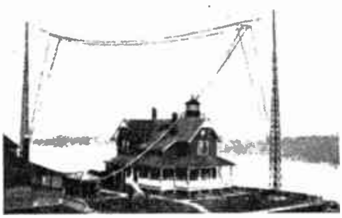


Part of the extensive antennae at Radio Central, New York, used for powerful broadcasting. The electron tube system is used for transmission.

AERIALS OF WORLD-FAMOUS STATIONS.



Aeroplanes in a fog, receiving two radio signals simultaneously, may steer a straight course by keeping a line which causes their loop aerials to hear both waves with the same intensity.
(Station of directive type.)



Lighthouse at Sea Girt, N. J., equipped for powerful transmission of compass signals and acting as a radio guide in the air and on the sea.

The Ambrose Channel lightship guarding New York harbor equipped with non-directive location device which neither night or fog can dim.

Courtesy of Radio News.

RADIO BEACON SYSTEMS DEVISED BY THE U. S. BUREAU OF STANDARDS.

a molecule contains several of them. The atoms of sodium and of chlorine, therefore, must be smaller than the molecule of salt. There are several billions of each in a drop of sea-water.

Research goes deeper yet. The atom, itself, consists of electrical particles known as "electrons," each with a positive or a negative charge. (Those with a positive charge are sometimes called "protons.") The positive electrons are nearly two thousand times larger than the negative electrons, and the proportion of each kind differs in every element. It is this difference in proportion which determines the difference in matter. The light gas, hydrogen, and the heavy metal, uranium, are both formed of electrons and nothing but electrons, but with different proportions and with different numbers in each atom, and also, with different structure. Hydrogen has but 2 electrons in its atom, one positive and one negative, an atom of uranium has 480 electrons, of which 240 are positive and 240 are negative.

So far as has been found out (for the science of the structure of the atom is still in its infancy) the atom resembles a solar system, with a nucleus (or sun) and negative electrons (like planets) revolving in an orbit around it.

This nucleus (in most elements, if not in all) has a positive charge. Around it revolve enough other negative electrons to hold the balance even, so that, under ordinary circumstances, every atom is neutral. Yet there is a great difference in the ability of this atomic structure to hold together. Some atoms are stable or do not change, others are unstable, and break up easily. The atom of helium (a light gas used for the inflation of dirigible airships) is remarkably stable, and holds together even under violent shocks or strains. The atom of uranium is so unstable that it flies to pieces of its own accord and turns into another metal, called ionium, and thence into a further metal, called radium. Finally, after a "life" of indefinite extent, it may turn into lead. This spontaneous break-up of the atom of an element is known as "radio-activity."

Most atoms are stable under ordinary circumstances, but unstable when subjected to severe strains, such as electrical charges produce. If an atom receives a severe shock—especially if it is a heavy and unwieldy atom—some of the planetary electrons are apt to fly off, the shock having disturbed the delicate gravitation of the atom. If an atom loses some of its negative electrons, the positive electrons become the stronger, and the atom is said to be then positively electrified. If another atom captures one or more of the escaping electrons, it secures more than its fair share of negative electricity, and then is said to be negatively electrified.

As Hugh was to find out later, it is this very instability of atomic structure which has made "broadcasting" possible, and some of the most interesting developments in wireless depend exclusively on a knowledge of the way in which these electrons behave.

In all atoms, moreover—especially in the more cumbersome types—there are a number of "free" electrons. To carry on the illustration of the solar system, these may, in a manner, be compared to meteors. The stability or the instability of the atoms of a substance as well as the kind of structure they possess determine the number of free electrons in that substance, and also determine the ease and speed with which they can move from one atom to another. Such substances as permit the free electrons to move about easily are known as good "conductors" of electricity; those substances whose atoms hinder the movement of the free electrons are known as "non-conductors."[1]

[1] Electric conduction is, as yet, imperfectly understood. While this book was in press, Mr. J. A. Fleming, inventor of the thermionic valve and one of the greatest living masters of the

It is evident, then, that "solid matter" is not solid at all. In the atom of uranium, there are 240 positive electrons in the nucleus, of which 92 are supposed to be effective, and there are 148 negative electrons as well; there are also 92 negative electrons flying around this nucleus like planets. In the atom of helium, four positive and two negative electrons compose the nucleus, and two more negative electrons revolve around it, like planets.

These "planets" are not near their "sun." In the case of helium, the distances have been worked out with a good deal of exactness. Suppose that the nucleus of a helium atom be regarded as of the size of a football, then, at a distance of one and one-fourth miles on either side, two golf balls would represent the planetary negative electrons. There is plenty of room between.

Yet the atom, itself, is inconceivably small. It is about a two-hundred-millionth of an inch in diameter, measuring the atom at the greatest range of its attraction, that is to say, in the case of helium, between the two golf balls, at two and one-half miles apart. How much more tiny must the electrons be!

The nucleus has a diameter of about one ten-

science of radio, wrote to the author, stating that "the problems of conduction are extremely complex, and, in parts, obscure."—F. R–W.

thousandth of the atom, and the electron is in size to the nucleus as a golf ball is to a football. It would take millions of billions of electrons to fill up the eye of the finest sewing-needle ever made.

In spite of their infinitesimal size, these ultra-invisible electrons have been weighed, counted, measured, and even their individual electric charges discovered. Thus it is definitely known that it takes exactly six million billion negative electrons to carry among them that quantity of electricity which is measured as equalling that amount conveyed by an electric current of one ampere in the time of one second.

Had Miss Ferguson been aware of all this modern development of scientific knowledge, she might have been able to give Hugh a more exact explanation of what had happened when he got the spark from his Leyden Jar. The spark was really a mad leap, made simultaneously by billions of electrons, across what was to them a vast expanse of space, greater than if a man should try to leap to a distant star.

When the boy had touched the brass knob of his jar to the negative pole of his frictional machine, the free negative electrons, which had been piled up at that pole, finding a path open to a place which was not overcrowded—the inner tin—raced through that path in billions. When Hugh took away the knob, the inner tin was loaded with all the free electrons it could hold. At the same time, as the teacher had suggested, the positive pole of the frictional machine was short of negative electrons.

When, therefore, the boy touched the wire from the outer tin to the positive pole of the machine, the free electrons in the atoms of the outer tin hurried across this new path in order to try to make up the deficit at the positive pole of the machine. When the jar was finally removed, the situation was that the inner tin was overloaded with electrons, and the outer tin was lacking in them. The inner tin had a power of push, and the outer tin had a desire to pull. There was, then, what is known as a "difference in potential," between the two metals of the Leyden Jar, or, in more usual phrase, between the two plates of the condenser. To use the common expression, the jar was "charged" with electricity.

Now, as Miss Ferguson had pointed out, electrically charged bodies of the same sign repel each other, while unlikes attract. With an understanding of the ways of electrons, the reason for this is easy to see. Two bodies negatively charged, that is to say with a surplus of negative electrons, keep away from each other because neither wants to get any more. But two bodies differently charged, that is to say, one with too many electrons and the other with too few, will come together at once, for each is desirous of evening up the balance in its atoms.

In Hugh's jar, therefore, there was a further cause of strain. The negative electrons in the atoms of the glass of the jar, not being able to escape because glass is a non-conductor which holds its atoms together tightly, stretched away as far as they could from the overcharged inner tin. Each individual negative electron of the billions in the glass was pushed from its usual relation to its nucleus like a piece of taut elastic. Since any non-conducting, or insulating material, separating two conductors is called a "dielectric"—whether it be glass, paper, mica, oil, or dry air—this strain may be called a dielectric strain. This force must be added to the difference in potential between the inner tin and the outer one.

Such was the situation when Hugh took away his charged jar from the frictional machine.

If, in such a case, the wire connecting the outside tin be sharply brought in contact with the brass knob leading to the inner tin, then the wire, being a good conductor, acts as a race-track along which the billions of surplus free electrons from the inner tin may rush round to even up the deficit in the outer tin.

This was what happened to Hugh when he received an electric shock. His body, which was as good a conductor of electricity as wire, acted as a race-track. The swift passage of billions of electrons along his finger, up his arm, through the body and down the other arm to the hand which was holding the outer tin was what gave him the electric shock.

But the shock which the boy had got, and which made him drop the jar, was due to more than a single passage of the electrons. The energy brought about by the difference in potential between the inner tin and the outer one was much greater than that.

So wild were these free electrons to ease the strain (or to reduce the difference in potential to zero) that too many of them went across and they sped too fast. In less than a millionth of a second, the whole situation was changed. Now, the outer tin had too many electrons and the inner too few; at the same time, the electrons in the glass sprang back the other way.

The two movements can be easily explained. In the first, it is as though a pail of water were suddenly emptied into a long, narrow trough; the water would surge backward and forward until it found its exact level and came to rest. In the case of the glass, it is like the action of the elastic in a catapult, which, when released, springs back too far and snaps sharply against the thumb-knuckle.

A millionth of a second later, again, the positions were reversed. Once more the inner tin was overloaded, but to a less degree; the electrons in the glass were stretched in the other direction, again, but not so tautly. And so, backward and forward, along the path made by Hugh's body, the electrons rushed, but fewer each time, just like a spring which vibrates on a shorter and shorter arc (the time of the vibration does not change), or like a swing which has received but a single strong push, and go on swinging backward and forward, less and less high each time, until it comes to rest. So, in the boy's Leyden Jar, the electrons oscillated backward and forward until the difference in potential was evened up and the electrical energy was at rest. All this happened in less time than it took the boy to let go the jar.

Had Hugh known all this, he would have had no difficulty in understanding the spark which he secured in his second experiment. In this second case, when he had picked up the wire leading from the outer tin in his glass-tipped wooden pincers, he had not touched it actually to the brass knob, but he had brought it very near. The path, then, was not a complete one. It was like a good road, leading from one town to another, but with a chasm in between, too wide for a traveller to jump.

Air is a non-conductor, just as is glass (though it is not so nearly complete) and this little distance or gap of air between the end of the wire and the brass knob kept the electrons from rushing over. As the wire came nearer, however, a point arrived at which the strain was sufficiently strong to enable the electrons to jump across. To refer to the example of the chasm in the road again, it is as though workmen were busy filling up the hole, and an impatient traveller leaped across it, as soon as it narrowed enough for him to do so, without waiting for the last spadeful to be put in. (A greater energy would enable the electrons to leap a wider gap, just as an athlete would jump over a chasm that a child could not cross.)

The electric shock which Hugh had received was due not to a single rush of the electrons, but to a number of such rushes, oscillating backward and forward. How could this be true in the case of the spark? If it took all the strength of all the electrons to leap the gap the first time, how did it happen that, in the succeeding oscillations, when the electrons were fewer in number, they still had enough strength to take the jump?

The answer is important in wireless telephony.

The first electrons which leaped across the air gap electrified the air. To phrase this more exactly: the speeding electrons created an intense electric field in the gap, with the result that some molecules of air received an electric charge, while others were resolved into the atoms of their component gases. Owing to the collision of the speeding electrons, many of these atoms had one or more of their planetary negative electrons knocked off, leaving them incomplete and positively charged. Such incomplete positive atoms are called "ions," and air in such a state is said to be "ionized."

Ionized air is a good conductor of electricity, fully as good as copper wire. The result was the same as if a complete circuit had been made. In a sense, then, the ionized air acted as a temporary suspension bridge thrown across the gap, over which the electrons could oscillate backward and forward with ease. When the strain was released, and the difference in potential fell to normal, the electric field disappeared, the ions dispersed by the kinetic energy of gases, the ionization of the air came to an end, the temporary suspension bridge vanished, and the air gap became a non-conducting gap again. (To de-ionize air quickly is one of the problems of radio operation.)

In all the various complications that are connected with the principles of wireless, none is more necessary to understand than the oscillation of the electrons in the spark-discharge of a Leyden Jar. The spark-discharge was the basis of all early wireless work, the first wireless message to be sent across the Atlantic was from a spark-discharge, and it is still the general method on board ship.

In modern work, the Leyden Jar has become a Leyden Plate or a condenser. It may take many different shapes, from a tube the size of one's finger to an aerial a mile long; it may possess either a small capacity or an enormous one.

All condensers, however, agree in this: they are conductors of electricity, separated by a non-conductor or dielectric. They are rendered of greater capacity in three ways: by increasing the size of the conductor plates, by diminishing the distance between them, and by using a dielectric of high resistance, or constant, such as air, oil, ordinary glass, mica, porcelain, specially prepared glass, and dry marble. A wireless aerial or antenna is nothing more nor less than a form of Leyden Jar or condenser, with the aerial wires acting as one piece of tinfoil or plate, the ground being the other, and the air—corresponding to the glass—being the dielectric between.

Just as Hugh used a wire to connect the outer tin of his Leyden Jar to the inner one, so the two plates of any condenser may be connected with a wire. This wire may be a few inches long, or a mile long.

If the wire be cut in the middle, a movable key may be inserted, the closing of which allows the electrons to pass, and the opening of which makes an air gap too great for the electrons to leap over. At any point in this wire, between the inside and the outside of a Leyden Jar, or between a wireless aerial and the ground, any number of other pieces of electrical apparatus may be inserted, to be set to work by the closing of the movable key, and thrown out of action by the opening of it. The entire operation of wireless—for short distances—may be done by means of a Leyden Jar alone.

In the log-house on the mountains, experiment followed experiment. Under the teacher's suggestions, and following his own growing sense of electrical perception, Hugh improved his methods day by day, until, at last, he found himself possessed of a condenser of large capacity, capable of giving a powerful spark. He had found out, too, how to combine several Leyden Jars together, either by connecting all their similar poles together (in parallel), or their opposing poles (in series). The result of the latter puzzled him a good deal, for, while connection in parallel naturally increased the capacity of the combined condensers, connection in series decreased the capacity, and neither he nor Miss Ferguson was sufficiently versed in mathematics to be able to figure out how several condensers could have less capacity than one.

The second month of the teacher's stay in Ants'-Hole Creek was drawing to an end by the time that Hugh's improved Leyden Jar was put in operation. In the meantime, the girl had become almost as much interested in the experiments as the boy himself; her chief care, however, was the overseeing of the electric treatments given to Mrs. Burke.

The moonshiner's wife had made many visits to the stead and her health seemed to improve with the action of electricity, though it was possible that a good deal of this improvement was due to the tactful suggestions in regard to food and hygiene made by the teacher.

The days approached when the girl must go to spend the last two weeks of the school term at the Iretons'. This time, there was no way of dodging it. To refuse to go there would so anger Sandy Ireton that a feud would be inevitable. Secret and treacherous murder would become of daily occurrence, and even women and children would not be exempt. With deadly enmity ruling the creek, there could be no hope of a school in future winters. The teacher saw this clearly. She realized that she must face the danger, unpleasant as was the prospect, or her stay in the creek would have been more productive of harm than of good.

Burke, who was one of the few men in the valley who had no fear of Ireton, took the occasion to suggest to him that, during the two weeks of Miss Ferguson's stay, it might be a good thing if Cram, the eldest son, could be sent away on a visit, or on some other pretext. Ireton met this suggestion with a blunt refusal, and in an ugly mood.

"Yo'-all," he said, "seem to think that I can't handle my own affairs. When I want yo'r advice, Wat Burke, I'll ask fo' it!"

"I don't need a man's leave afore tellin' him thar's a rattler right where he's goin' to put his foot, Sandy Ireton! "

" I'll look after the rattlers, ef it's my boys yo're meanin'! An' they'll keep still, ef I have to break their necks to do it! "

After that, there was nothing more to be said. The next day, the teacher packed her slender baggage and drove down to Ireton's place.

There was trouble right from the very start. The boys knew that their father was watching them closely for any evidence of roughness, and listening for any rude word. Cram, maliciously, went out of his way to be over-polite. He was effusive and familiar. The girl would a thousand times rather have seen him angry and sullen, for she could not openly resent a courtesy, however unwelcome.

Sandy Ireton, while on the guard against any sign of mischief or ill-will, was not subtle enough to be sensitive to that kind of over-politeness which is so obnoxious to a woman when coming from some one she does not like. On the contrary, the father praised his eldest son for not showing any grudge.

Cram, realizing this lack of perception on his father's part, saw that his game was well covered. Day by day he became more and more odiously familiar. The girl had to endure it, for fear that some ugly scene in the house might wreck in a moment all her good work of the two months preceding. She managed, however, to let it be seen that she was keeping Cram at a distance.

The first week passed off without any serious incident, and there was only one week more to be endured when Miss Ferguson heard indirectly that Cram Ireton had sworn not to let her leave the creek until she had shown him some sign of friendliness. That afternoon, when Cram appeared at the schoolhouse and insisted on escorting her home, she lost her temper and gave him so severe a tongue-lashing that even his boldness was cowed, and he slunk away, whipped, but vowing revenge on the high-spirited young teacher.

The room in which the girl slept, at the Iretons', was on the ground floor, of course, for none of the cabins in the creek valley had a second story. Sandy Ireton, who misdoubted the trickery of his boys, especially that of Will, the youngest, had put in double bolts on the inside of the door and a big bar across as well. There was no forcing of that door, made of planks of oak!

Hugh had heard her contemptuous and severe denouncement of Cram Ireton, and had seen him slink away. Knowing the nature of the young fellow, he got intensely anxious. It would not be like Cram to let such a public insult be forgotten or go unrevenged.

That night, the boy decided to mount guard over the teacher's sleep. It was bitterly cold, but, as yet, little snow had fallen. Wearing his father's coon-skin fur coat, and carrying his blankets and a shot-gun, Hugh went by a mountain path through the woods to a point behind the Ireton house, where he could see the teacher's window. He had learned, through his father—who had asked Miss Ferguson herself—that the door could not be forced.

The first night, all was peaceful, though Hugh suffered a good deal from the cold. The second night, all was quiet likewise; and the watch was easier, for there was snow in the air, and the wind was still. It came on to snow, that day.

About midnight, on the third night of Hugh's watch, while he was fighting hard against sleep, he saw Cram and Ollie steal quietly out of the back door.

Instantly he was on the alert.

This spoke of danger!

The absence of Will, the youngest, who was the most mischievous and the trickiest of the three, gave to the presence of the two elder brothers a sinister aspect. More than mere mischief was in the wind, and Cram's reputation was an evil one.

Well hidden himself, Hugh watched them carefully.

Their steps muffled by the snow, the two young fellows came to the teacher's window. Each had something in his hand, though what it was, Hugh could not see, for their motions were obscured by the dark. Only their silhouettes, against the snow, stood out clearly.

It seemed as though one of the small square window-panes must be loose, for the boy thought he saw Cram put his arm through the window, as if it were open, and make the gesture of throwing something. Then there was a delay of a few moments.

Presently, absolutely without noise, the entire window-frame was moved out, each of the boys holding one side. Evidently it had been loosened the day before, and had merely been held in place during the evening by a couple of screws.

With Ollie giving him a leg-up, Cram vaulted on the window-sill, and threw one leg over, as though to jump into the room.

At the same instant, Hugh, who had come to a kneeling position, his shotgun at his shoulder, took aim at Cram's other leg and pulled the trigger.

The shot rang out in the silence of the night, and was echoed by a yell from Cram, who fell from the window-sill and lay writhing on the snow.

Few seconds elapsed before the back door burst open and Sandy Ireton ran out, rifle in hand.

Hugh, realizing that, if he tried to escape, his tracks would be visible in the snow, and that he could not hope to outrun Ollie and his father together, came forward boldly, shotgun in hand.

At the sight of him, Sandy Ireton's rifle flew to his shoulder, but, seeing that the boy was approaching him and not running away, he put it down again, and gave a cursory glance at Cram's wounded leg. When he looked up again, Hugh was quite near.

" 'Twas yo' did the shootin'? "

" I shot," came the quiet answer.

The man looked at the window without its frame, at his two sons, and at Hugh alternately.

" Yo've been watchin', then? "

" Every night, for three nights. Reckon there was need."

The father half-turned and took Ollie by the scruff of the neck.

" Answer, yo' young hound! " he said furiously. " What have yo' done to the girl that she a'n't moved? "

The young fellow tried in vain to shake himself free from his father's grip.

"I a'n't done nothin'! Cram, he threw on the bed a rag wi' some dope on it he got from town. He said he wanted to play some trick on her so'd the laugh'd be on her instead of on him."

"So! Yo' stay right thar, Ollie! If yo' move a step, I'll flog yo' wi' a thorn switch till thar a'n't an inch o' your hide that a'n't bleedin'!" He turned to Hugh. "Yo' stay thar, too!"

"I hadn't conjured to run," the boy responded sturdily.

Sandy Ireton vaulted through the window. As Ollie had said, a large cloth smelling strongly with a sickly odor had fallen over the teacher's face, and she was breathing in the fumes. Ireton picked the cloth off with a jerk, and threw it out of the window.

In a minute or two, the crisp air coming in through the vacant window-space revived the girl.

"You, Mr. Ireton!" she exclaimed, in surprise and reproach, and pulled the bedclothes closely about her neck.

"I a'n't goin' to hurt yo'. Are yo' feelin' all right?"

"My head swims a little. Why do you ask?"

Then the girl noticed the window-frame.

"Oh, look at the window! Has it blown out in the night?"

"It's been taken out."

The teacher guessed at once.

"By ——"

"Ay, by Cram. Listen, an' yo' can hear him groanin'! He's lyin' out thar on the snow, his foot an' leg peppered wi' shot."

"Who shot him?"

"The Cecil boy. Seems he's been watchin' outside yo'r window."

"What! This cold night, Mr. Ireton?"

"Several nights."

He paused a moment.

"Yo'd better go to sleep again, if yo' can," he said. "I'll put the window back. Yo' won't be troubled again!"

He vaulted back through the open space, and, reaching the ground, dealt Ollie a heavy cuff on the side of the head.

"Pick up that window an' help me put it back! Yo' hear me!"

The two of them replaced the window, and the younger lad showed how it had been loosely held in place by two long screws, trying to excuse himself for his part in the escapade by saying that his brother had forced him.

"We'll take Cram in, an' find out how much he's hurt," said Ireton, ignoring his son's excuses.

"Can I help?" asked Hugh. "Go for the doctor, or anything?"

"No! Yo've done enough fo' one night!"

Then, his better nature triumphing over his anger and his shame that such a thing should have happened under his roof, he added:

"But I don't hold yo' no grudge fo' shootin'. Maybe yo've saved my house from gettin' a worse name. Mo'! I give yo' credit fo' what yo've done!"

CHAPTER IV

DANCING FROGS' LEGS

As it chanced, the cartridge which Hugh had in his shotgun when he had fired at Cram Ireton had been loaded only with bird-shot; consequently, the injuries suffered by the young fellow were not serious. There was some danger of blood-poisoning, however, and Dr. Cameron had been sent for. He came in the course of the morning.

"Pity the shot didn't go through your head!" was his blunt comment to Cram, when the night's exploit was explained to him. "It's scoundrels like you that give the valley a bad name. If it wasn't for my profession, I'd let you get gangrene, and say, 'good riddance'!"

This verbal attack did not in the least prevent the doctor from exercising the greatest care in his work, and in doing the utmost possible to keep his patient from suffering.

Ireton, though always ready to take offence, made no retort. He knew the doctor's gruff manner, and how oddly it consorted with his gentle touch, and he was well aware that no man lived a more self-sacrificing life than the rough-tongued physician whose word was fate in a dozen mountain valleys.

"Is he goin' to be lame, do yo' reckon?" the father asked.

"I'm sorry to say he won't! It's the folks who aren't worth powder and shot enough to blow them up, who always get well. Here's this ill-mannered lout of yours who'll be as limber as ever he was, in a month, while Mrs. Burke—who's one of the finest women in the valley—will be an invalid all her life."

"But she's gettin' a lot more spry, folk say."

"Much they know about it! She's feeling better, which is a very different thing."

"Do yo' conjure that Cecil boy's contraption does any good?"

Dr. Cameron shrugged his shoulders, working busily with his instruments the while.

"Since I've told you she's feeling better, it stands to reason that the electrical treatment must have done her good. It won't cure her, if that's what you mean.

"I'm going up to the Cecils' this morning, to take a look at the machine, and at the boy. I don't know the youngster at all—haven't seen him since the day he was born. He must have pluck as well as brains to have sat out there these cold nights just from a sense of loyalty. Shows a good streak. He'll go far."

"He'll go farther when I get at him!" growled Cram, between groans.

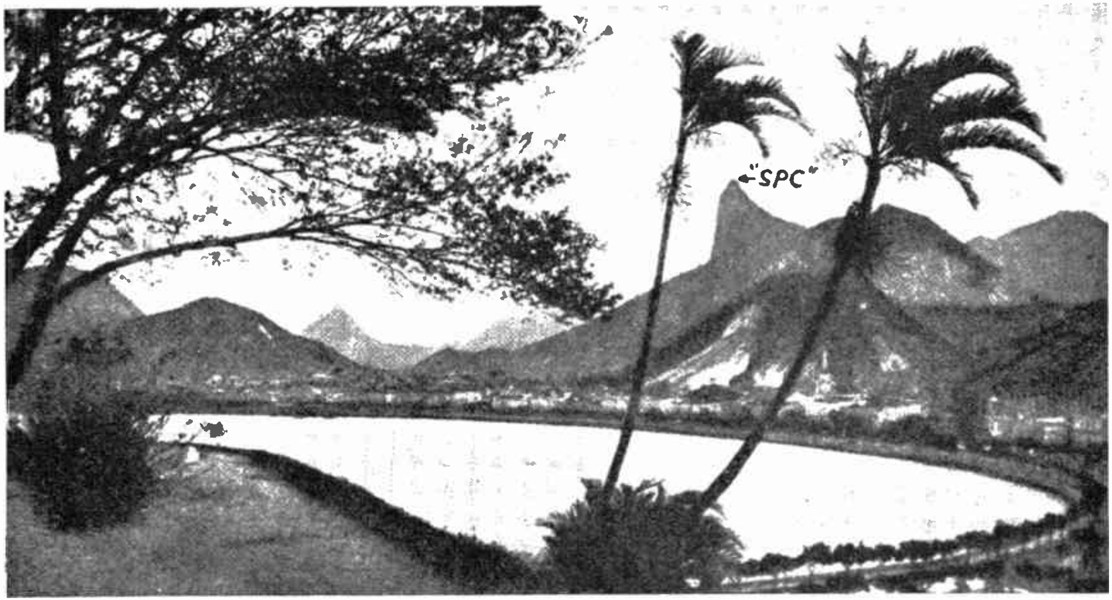
The doctor knew the superstitious character of his mountain patients, as well as the desire for revenge, and he answered swiftly:

"You're as big a fool as you are a scoundrel, Cram, if you don't know that, with an electrical machine like that boy's got, he can cripple you any time he wants to. Lightning can hit at a distance, remember! It's true that he doesn't know how to handle that end of it, yet. But you don't need to worry about that! I'm going to show him how, to-day, just for your special benefit."

Cram doubted this statement a little, but, none the less, his doubt was mingled with dread. After all, lightning was a dangerous thing to play with.

"Yes," the doctor continued, "electricity can kill as well as cure. In some of the States they use it, instead of hanging. I don't know whether you'll be electrocuted or hanged, Cram, but if you go on the way you've begun, you'll surely end on the gallows or in the electric chair.

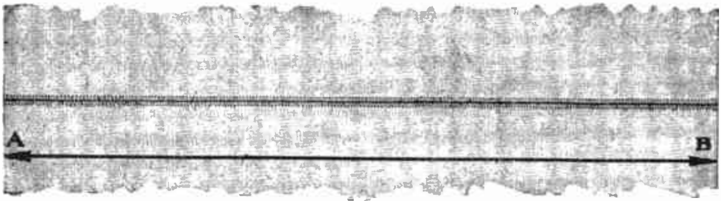
"And, what's more," he went on, "I want you to



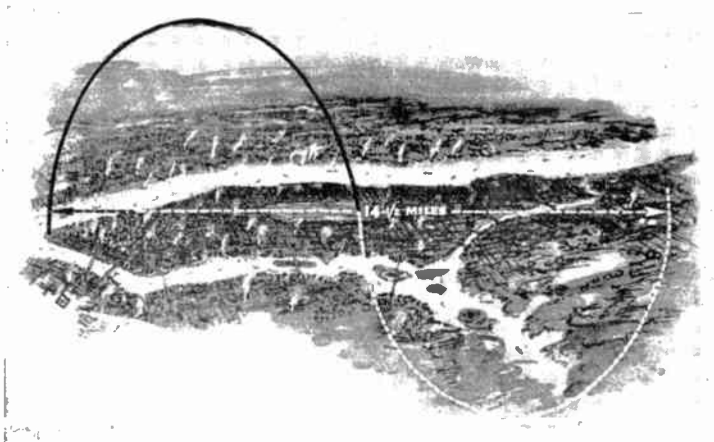
Courtesy of Radio World.

LINKING THE TWO AMERICAS.

The Westinghouse International Broadcasting Station (SPC) on a high peak above the harbor of Rio Janeiro. Pan-American Congresses in Washington have been heard through this station from Argentine to Peru.



The illustration is already magnified more than 10,000 times. The distance from A to B represents the thickness of a piece of newspaper. The waves shown are those of ultra violet light. Scientists have measured X-rays which are a million times smaller, and radio-active rays which are smaller still.



Courtesy of Radio News.

A radio wave of moderate wave-length, in daily use at Bordeaux, France. As all radio-waves travel at 188,100 miles per second (300,000,000 meters) this wave has a frequency of 12,840, in other words over 12,000 such waves pass a given point in a second.

ELECTRO-MAGNETIC WAVES COMPARED: ULTRA-VIOLET LIGHT AND RADIO.

remember this—if I hear that there's been any shooting, I'll come and handle you myself so that you won't ever get up from your bed, even if you live to be a hundred! I'll fix you, so that you're in pain, night and day. And I won't need to use a gun, either! "

This was a fearful threat. To run the risk of being shot, if he tried any treachery, meant little to Cram. That was a chance which had to be taken. But he had all the ignorant person's fear of the unknown, and the menace of the doctor's science kept him quiet. Not for an instant did he doubt the power of the glittering instruments and the battered medicine-case.

The surgical dressing over, Dr. Cameron went to the schoolhouse, and, with the teacher's permission, told the exact story of what had happened the night before. He did not mince his words, and, by the time he had finished, he had built up in the minds of the children a firm determination to keep a close watch on the Ireton boys, during the remaining four days of the teacher's stay.

The doctor had already curtly informed Sandy Ireton that the girl would return to the Burke home for those four days, and Ireton, ashamed to the heart on his son's account, had made no objection.

When school was dismissed, the doctor drove up to the Cecil homestead with Miss Ferguson, Hugh standing on the slats of the buckboard, behind. During the drive, the doctor questioned the lad closely with regard to his electrical knowledge and experiments, and, arrived at the stead, examined the frictional machine and the Leyden Jar with great care.

"What's the voltage of your jar, Hugh?" he asked.

The boy looked bewildered.

"I don't know what voltage means, Doctor," he answered.

"The number of volts, boy; the pressure! No? You don't know! Or the capacity of the jar, in farads?"

Hugh shook his head, and Miss Ferguson, to whom the doctor turned in protest, made a gesture of negation, likewise.

"I don't know, either."

"Thunder! But you'll have to learn electrical measures, Hugh, if you ever want to be able to do anything with electricity! You'll be like a man trying to sell corn, who doesn't know the difference between a peck and a bushel! You've got a Leyden Jar, there, and you don't know how much electricity you can put into it, nor how much you can get out of it? But that's absurd!"

"Suppose you explain how he ought to do it, Dr. Cameron," suggested the teacher. "I'm sure I couldn't."

The doctor tipped back his old weather-beaten hat, and scratched his head.

"How in thunder can I begin, when the youngster doesn't know anything? I can give him the equations, but he wouldn't understand them. He'll have to learn mathematics. Why haven't you taught him, Miss Ferguson?"

"In two months, Doctor?"

"Eh! That would be a bit swift, sure. Well, I'll try to give him an idea, anyway. Look here, Hugh! You know what's the difference between a quart jar and a gallon jar, eh?"

"Sure. One holds a gallon, and the other, a quart."

The doctor sniffed audibly at this answer.

"Which is the bigger?"

"The gallon jar, sir."

"Very good. Now bigness isn't only a question of content, it's also a question of power of work. It isn't always the fattest boy who can do the most. See here, why does your water-wheel go round?"

"Because the water falls on the cups, and ——"

"If the water had only an inch of fall, would it turn the wheel?"

"Not unless there was a lot more of it; no, sir."

"Good, I'm glad you understand that. Then you can see that the height of the fall of water causes work. So does quantity. If you put a ten-gallon tank, with a tap in the bottom, on a bench ten feet high, when would the force of the water running through the tap be greatest—when the tank was full or when there was only a little water at the bottom of it?"

"When it was full, sir, of course."

"Just so. It would have more pressure, and therefore more power of work. Don't forget that! Large cities get their water supply that way. Reservoirs are built in the mountains, higher than the level of the city, and the pressure of the water in the reservoir forces the water through the pipe and even sends it to the top stories of a high building. That pressure can be measured.

"Now, any condenser, such as your Leyden Jar, my boy, is a reservoir of electricity. As you told me in the buckboard, you know that there is a strain between the two plates. That strain is pressure. That pressure can be measured, and it is measured in volts,[1] just as distance is measured in yards, or weight in pounds.

"The 'volt' is named after an Italian scientist called Volta, who, because of some experiments on frogs' legs, invented the first voltaic pile or electric battery. When I get back to Foljambeville, I'll send you a battery I've got there, and a simple book on electricity, as well."

"Oh! Thanks ever so ——"

"Don't thank me; thank yourself. If you hadn't shown that you were worth it, I wouldn't have bothered about you. But if you really want to achieve something in the electrical line, you'll have to work hard on your arithmetic; if Miss Ferguson can give you a few simple ideas on algebra, before she goes, so much the better."

"I can do that, Doctor, I believe," the teacher put in hastily, "just the beginnings, though."

"That'll be all he can take in, probably. You ought to learn, Hugh, as soon as you can, how to

[1] The "volt" is the unit of electrical pressure; it is the electromotive force which produces a current of one ampere through a conductor with a resistance of one ohm. The "ampere" is the unit of electric current; it is based on the quantity (.001118 gram) of silver deposited per second by the action of an electric current passed through a solution of nitrate of silver. The "ohm" is the unit of electrical resistance; it is based on the resistance to the passage of electric current of a thin thread of mercury (106.300 centimeters in length, 14.4521 grams in mass) at the temperature of melting ice.

measure the capacity and the pressure of your Leyden Jar. It's a Tom-fool business to be able to work an apparatus, and not know why it works.

"I've seen youngsters with a wireless set—you don't know what that is, yet, Hugh—who can fiddle about with switches and levers a little, and, because of that, think they know it all. That's about as idiotic as to say that because a man knows how to pour drops from a bottle, he's a doctor, although he doesn't know what's in the bottle nor what the medicine will do!

"I'll try to give you an idea of electrical measurement, just the same. You've seen a bicycle wheel tire?"

"Yes, sir."

"And you know that it has to be pumped full of air, eh?"

The boy nodded.

"Now, air pressure is measured, in that case, on the basis of a pound to a square inch. I'll give you an example which isn't exact, but which will be near enough.

"Suppose there was a hole just an inch square in that bicycle tire, and there was a plug weighing a pound and fitting that hole exactly. You can see for yourself that if the tire was only half full of air, the pressure wouldn't be big enough to lift out the plug. But, if you went on pumping air into the tire, it would get so full and the pressure would be so great that, at a given force, it would blow the plug out of the hole. In that way, you could measure the air pressure or the capacity of your tire.

"The capacity of a condenser, like your Leyden Jar, can be measured, too, though the way of doing it is a bit different. The result is stated in units called 'farads,'[1] named after the famous English physicist, Faraday. This unit is rather big, however, for such things as a Leyden Jar, and it is easier to reckon in millionths of a farad, or a microfarad.

"I haven't got time to stop and figure out the pressure value and the capacity of that Leyden Jar of yours, Hugh, because it isn't easy to be exact without a good deal of calculation. Since you say, though, that it gives nearly a half-inch spark, I should judge, roughly, that it ought to hold a voltage of about 10,000 volts or more, that its capacity is

[1] The "farad" is the unit of electrical capacity, in which a potential difference of one volt gives a charge of one coulomb. The "coulomb" is the unit of electrical quantity, being that transferred by one ampere in one second. The "henry" is the unit of electrical inertia or inductance, being one volt of induced electromotive force when the inducing current varies at one ampere per second. The "watt" is the power expended by a current of one ampere in a resistance of one ohm. The "joule" is the energy expended in one second by a flow of one ampere in one ohm. (The watt and the joule are mechanical units, electrically considered.)

about 1/500th of a microfarad, and that its energy is about three-eighths of a joule. Therefore, on a spark of nearly half an inch in length, it would produce several thousand oscillations, each one of which would take about three-eighths of a millionth of a second. If you could set it directly to mechanical work (without loss of power by friction), its energy would be enough to raise a pound weight three inches from the ground, or a three-pound weight, one inch.

"A little later," the doctor went on, smiling at the boy's utter confusion in this maze of figures, "you'll be able to reckon all this out for yourself. It's really not so hard as it sounds. By the way, have you learned to write, yet?"

"He writes quite well, Doctor," declared the teacher, proudly.

"Very good." The speaker took out his pocket-book and handed the boy some stamps. "Go ahead with your experiments, and write to me if you get stuck."

But Hugh made a gesture of refusal.

"I a'n't got any money to pay for them, Doctor," he said.

The other repressed a smile at this sign of mountain pride, but he replied with gravity:

"On the contrary, I owe you money. I prescribed electricity for Mrs. Burke, and you've given her eight treatments, haven't you?"

"Yes, sir; she's been here eight times."

"The regular price for electrical treatment is five dollars, but you're hardly an expert, are you? Certainly two dollars would be fair enough."

"I hadn't conjured to charge anything, Doctor!" declared Hugh, a little indignant.

"Of course not, but I had. I live by doctoring, you know, boy. If I order a thing, sick folks have to pay for it, eh? Don't you worry. That's sixteen dollars that I owe you, for I'll put it on my bill to Wat Burke."

Hugh looked dubious, for he was inwardly convinced that this whole statement was but an excuse, but he could not very well suggest that the doctor was not telling the truth.

"If that's it, Doctor," he put in, "you can take that money to pay for the battery an' book you were talkin' of."

"It's agreed," Dr. Cameron answered, shaking hands with the boy as he clambered into his buckboard.

He turned around to say to Hugh, "I'll send you the battery as soon as I get back to Foljambeville, and the book as soon as it comes from New York. But get at your figuring, as hard as you can."

The electrical definitions with which he had been bombarded puzzled Hugh a good deal, but he had a fairly retentive brain, and they set him thinking.

After dinner, he took down his shotgun, and, on the long walk with Miss Ferguson to the Burke house—for it had been decided never to let the teacher walk alone and unarmed—he asked a quantity of questions, only a few of which the girl could answer.

He outlined to her what he had grasped from the doctor's talk. In the wire which connected the outer and the inner tins of his Leyden Jar, both at the time that he had received the electric shock, and at the time the spark was produced, there must have been a current passing. This "runnin' around of electricity," as he phrased it, must have been what the doctor meant by "current," and must have been what ought to be measured in amperes. The boy began to understand, too, what was meant by resistance, and grasped the fact that a resistant wire could get hot, although he had never seen an electric light.

In point of fact, the galvanized wire which Hugh had used was by no means a perfect conductor of electricity. In other words, the electrons which went racing round the track when the two plates were connected were considerably hindered in their course. The atoms of the metal wire resisted their passage, and it is this resistance which is measured in ohms. A good illustration of this is seen in the frictional resistance of a water pipe to a pressure of water. If the pipe be too long or the diameter too small, the water may not flow at all, the friction overcoming the pressure. In the same way a long wire gives more resistance to the electric current than a short wire, and a thin wire has more resistance than a thick one.

Such resistance, like all forms of friction, produces heat. It is the resistance of the atoms of the thin carbon filament or the metallic wire in an electric light bulb to the passage of speeding electrons (the electric current) which produces so much frictional heat that the wire gets white-hot or incandescent and therefore gives out light.

There is, moreover, in all substances which lie in the path of an electric current, a type of inertia called electrical inertia or inductance. This is the property which makes it difficult to start something moving, and equally difficult to stop it. A locomotive has to use more force to start a train than to keep it going once it is in motion; likewise, powerful brakes have to be used to stop a train, even though the steam has been shut off for several minutes.

In similar fashion, an electrical circuit—which is any combination of electrical apparatus inserted between the positive and negative poles of any electricity-producing device, be it frictional machine, battery, or generator—resists the start of any current passing through it, and also resists any attempt to cut it off. Some circuits—depending on their length and the various pieces of apparatus which may be inserted therein—have more inductance than others, and in many of them, devices, such as choke coils, are put in deliberately to increase the inertia, when needed. This principle of inductance (which should not be confused with "induction") has been brought to a point of high usefulness in wireless work. It is measured by the unit of the "henry," named after Joseph Henry, an American physicist.

Dr. Cameron's reference to "frogs' legs" had reminded Miss Ferguson of one of her school stories in connection with the discovery of the electric current. In trying to answer some of Hugh's questions, during the walk to Burke's house, it occurred to her to tell the story of Galvani, thinking it probable that the boy's intense eagerness to learn might enable him to get some information therefrom which he could put to practical use.

"Did you notice, Hugh," she asked, "that Dr. Cameron, when he was talking about the battery, told you it had been invented because of some frogs' legs?"

The boy made a grimace.

"He was tryin' to be funny!"

"No, he wasn't; he was telling you a real historic fact, like Gilbert's discovery of the electricity in other things besides amber. It sounds queer, I know, but frogs' legs actually were what led to the discovery of the electric current."

"Honest?"

"Yes, really!"

"How was it, Miss Ferguson?"

"It's quite a story, Hugh! It happened a long time ago, in 1780, less than forty years after the discovery of the Leyden Jar.

"One day, a famous Italian doctor, named Galvani, who was professor of physiology in the University of Bologna, undertook some experiments to learn a little more than was then known about the anatomy of muscles and of nerves. In order to have a supply of material for experiment, he went into the market and bought a number of frogs' legs, the frogs having been caught and killed that morning. In France and Italy, you know, Hugh, frogs' legs are considered very good eating."

"They are?"

"Oh, yes; and very nice they are, too!

"Well, soon after he got back home with his purchases, Galvani was called to dinner, and so he hung these frogs' legs on copper hooks which were attached to the iron rail of his balcony. That was just accidental, because he had twisted up these hooks from a piece of copper wire which chanced to be lying around. While he was eating his dinner, there came on a storm of wind and rain.

"Returning to his study, Galvani was surprised to see the legs of the dead frogs twitching and dancing, just as though they were still alive."

"What!" interrupted Hugh.

"It's perfectly true. The legs were twitching, as if they hadn't been cut off their bodies, several hours before. Galvani watched them closely, and noticed that the twitching occurred every time a frog's leg—which was strung on a copper hook—was blown by the wind against the wet iron of the railing. Having been for some time puzzled to explain how sensations are carried by the nerves to the brain and back again, Galvani jumped to the conclusion that they must be carried by a new kind of electricity, which he called 'animal electricity.' There are people who still believe in it, and call it galvanism or 'animal magnetism.'[1]

"Then Volta, another Italian professor, began to repeat Galvani's experiments. He was a physicist, and better trained than a doctor to understand what had happened. He proved that the dancing of the dead frogs' legs had nothing to do with 'animal electricity,' but that it was solely due to some kind of an electrical difference between the copper of the hooks and the iron of the wet rail, and that the muscles and nerves of the frogs acted only as conductors.

"You see, Hugh, it was a good deal like the time you got the electric shock. It wasn't any electricity in you that made you drop the jar, but your muscles and nerves carried the electricity from the inner tin to the outer one, and back."

"I can see that, all right, Miss Ferguson! But I don't see why copper an' iron ought to make electricity, just 'cause they're wet."

"I don't know why, but they do. I just know

[1] Strictly speaking, "animal electricity" actually exists, and may be found in the electric organs of the torpedo-fish, the torpedo-ray, and the electric eel. The currents produced show all the known powers of electricity; they magnetize a needle, cause electrolysis, and emit the characteristic spark.—F. R-W.

that when plates of different metals, or of almost any metal and a piece of carbon, are partly dipped in a solution of salt or acid, and the tops are connected with a wire, electric current begins to flow."

"Without any rubbin' at all?"

"Without any rubbing. Just like that!"

"But why? How can electricity start right out of doin' nothin'?"

"I tell you I don't know, Hugh. All I can do is to go on and tell you the story of what Volta did, as far as I can remember it.

"After he had made up his mind that the metals produced the electricity, and not the frogs' legs, Volta set to work and cut a number of small discs of copper and of iron. He made a pile of these, with pieces of wet flannel in between, in order to copy, as nearly as possible, the conditions on Galvani's rain-swept balcony.

"Then, to avoid any possibility that 'animal electricity' had anything to do with it, he put the frogs' legs aside, and connected the copper discs and the iron discs with two separate wires. When he brought the ends of these two wires together, he found that electricity began to flow between the copper discs and the iron discs.

"He had made the first electric current!

"This apparatus, which soon became famous, was known as the Voltaic Pile.

"Feeble though this current was, yet it was enough to show Volta that he was on the right track. The next thing to be done, clearly, was to find some means of making the current stronger. His first experiments were the combining of different metals, and he settled upon copper and zinc. Then it occurred to him that perhaps some liquid other than water might give a more powerful effect, if placed between the metals.

"Knowing that salt water was a better conductor of electricity than fresh, Volta took a glass jar, filled it half full of salt water, and put a zinc bar and a copper bar in the solution, taking care that the electrodes should not touch each other. When he connected the tops of these two bars with a wire, he realized that he had secured a much larger current, for the wire became hot.

"Recalling the early discoveries which had been made on the electrical properties of sulphur, Volta then decided to try a solution of sulphuric acid. Here he attained what was really a triumph! The current which flowed between the copper and the zinc was strong enough to make a tiny spark.

"Thus Volta developed the electric current which works such wonders in the world to-day, and the jar with plates of copper and zinc partly plunged in a solution of acid is the famous Voltaic Cell, several of which together are known as an electric battery."

"But I still don't see why putting metals in acid makes electricity, Miss Ferguson!" the boy protested.

"You'll have to write and ask Dr. Cameron, then," she answered smiling. "I'm sure I don't know why. It's much too deep for me. There's something chemical about it, I think, and I never learned chemistry."

As a matter of fact, while the Voltaic Cell or the electric battery of several such cells has, for more than a century, been the foundation of all electrical work, the underlying causes of its action have only recently become known.

Certain substances, principally metals, are found to possess a wide difference of electric potential, one from the other, when placed in a solution of certain salts or acids.[1] Zinc and copper are the most familiar examples of these metals. Such substances are called "electrodes." The solutions in which the electrodes are placed are known as "electrolytes."

[1] The actual reason for this is obscure. It is probably due to structural differences in the component atoms; the subject of atomic irregularity during chemical change lies outside the scope of this book.—F. R-W.

Ordinary salt water and a weak solution of sulphuric acid were the solutions most used during the early developments of electrical science.

These electrodes vary greatly in their powers. In the following list of ten substances: zinc, iron, nickel, lead, tin, copper, mercury, silver, platinum, and carbon, the electric current will flow readily from any one of them to any other further on in this list; the more widely separated the substances are in this list, the greater will be the current-flow.

Thus zinc and carbon, standing at the opposite ends of the list, are the substances with the highest mutual difference in potential. Being commercially available, moreover, they are widely used to-day, both in "wet" (Leclanché) cells, which are employed for such purposes as ringing electric bells, and in "dry" cells, such as are employed for pocket flashlights.

There are many different electrolytes, solutions of sulphuric acid, copper sulphate, potassium chloride, sodium chloride (common salt), sal-ammoniac and ammonium chloride being the most common; the last two in the list are in general use for "wet" cells and "dry" cells respectively. Ammonium chloride in a "dry" cell is in the form of a moist paste, so that it will not spill.

The electric battery, consisting of several Voltaic Cells, is all-important to wireless. Without it, nothing ever could have been done. All early experiments with the electric current were done with it. The first successful transmission of radio messages was accomplished with power taken from a three-cell battery, and, to the present day, it is as necessary a piece of apparatus in wire telegraphy as in wireless.

It is important, then, to grasp exactly what was the discovery to which the dancing of the frogs' legs chanced to lead.

In the simplest form of Voltaic Cell, a copper plate and a zinc plate are partly immersed in dilute sulphuric acid. The tops of the plates, or electrodes, are connected with a wire. The copper electrode is termed the positive terminal, or pole; the zinc electrode is known as the negative terminal, or pole. Current always flows, through the wire, from the copper to the zinc.

As soon as these electrodes are connected and current begins to flow, bubbles of gas (hydrogen) appear on the copper plate. After a time, it is seen that the zinc is beginning to dissolve (or to form compounds). Clearly, then, the current which is passing through the wire from copper to zinc, out of the solution, must also be passing from zinc to copper, in the solution, in order to form a circuit.

Since the electrodes are not connected in the solution, it follows that there is a "liquid gap" between them, like the "air gap" in Hugh's Leyden Jar. In order that the current may leap this "liquid gap," the solution must be ionized, just as the "air gap" was ionized to allow the electrons to take the leap.

These chemical changes (known as "electrolysis") produce physical and atomic changes, allowing the current to pass. As the current passes, it decomposes the solution, electrifying some molecules of the compound, and ionizing some of the atoms, allowing free electrons (the electric current) to pass through the solution, from zinc to copper, in a steady stream.

This electric current, moreover, sets up a wild whirling of ionic forces in the solution itself. The positive ions move at high speed toward the positive electrode or "cathode," and the negative ions with even greater velocity toward the negative electrode or "anode." (Sometimes, for clearness, these ions are known as the "cat-ion" and "an-ion," respectively.) If the electric current be passed through a solution containing metallic ions (silver, for example) the metal will be deposited by the positive ions on the cathode. This is the basis of "electroplating," such as "silver-plating" for forks and spoons, or "gold-plating" for watch-cases, and of "electrotyping."

When this somewhat complicated action in an electrolyte is considered, it becomes clear that Hugh's surprise was a most justifiable one when he declared that he could not understand how the electric current could suddenly spring out of nothing. It showed that the boy had unconsciously grasped the profound scientific truth that energy cannot be created, it can only be transformed.

In his rubbing of the amber and the glass with the flannel and the silk, respectively, it was the boy's own muscle-power which had been transformed or converted into electricity; in his frictional machine, it was the mechanical power of the water-wheel which was converted into electricity; in the Voltaic Cell which the teacher had described, it is chemical energy which is converted into electricity.

It was true that Dr. Cameron had promised to send him an electric battery, but Hugh knew that it might be a long time before any one chanced to be coming from Foljambeville to Ants'-Hole Creek, and he was much too impatient to wait as long as that.

He wanted to make a Voltaic Cell, himself, right away.

As soon as he got home, after having seen the teacher safely to Wat Burke's house, the boy began to puzzle out how he could make a battery. The real trouble facing him was to get hold of zinc and copper.

Neither of these was to be found about the place. The only metals which were handy were tin, from tin cans (really, tinned iron), and lead, from bullets. Now, Miss Ferguson had said nothing about lead, but she had mentioned carbon. The boy remembered that, once, she had told him that charcoal was a kind of carbon.

Tin and charcoal, for electrodes, were easy to find; salt water, for an electrolyte, was no harder to get. He could even try that experiment before going to bed.

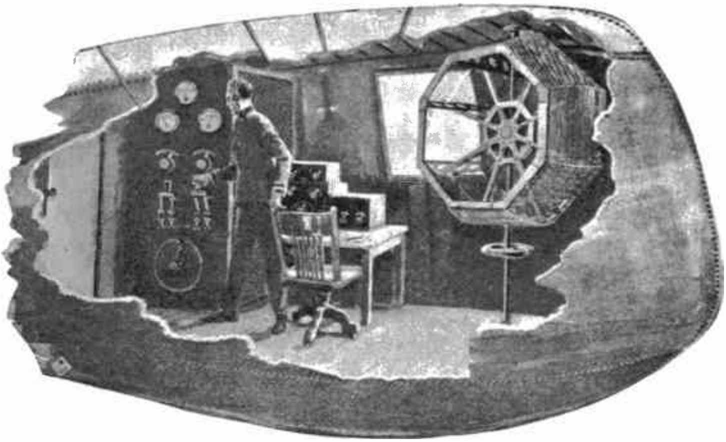
Taking another "gem" jar, the boy half filled it with salt water, and then put in it a strip of tin and a long stick of charcoal. Next, he connected the tops of the two electrodes with a wire. So far, he had done as much as Volta, though, of course, he was copying and not originating.

But there was one thing he had not thought of: how was he to tell that an electric current was passing? He had quite forgotten to ask Miss Ferguson how Volta knew.

Undoubtedly, he thought, a frog's leg would show him, since it was so sensitive a conductor. But it was the dead of winter, and there were no frogs to be caught! He must test it out on himself. Cutting the wire in the middle, and leaving the ends almost but not quite touching, Hugh put his finger on the gap. A faint, a very faint prickling sensation rewarded him. That, and no more, but even that was enough to show him that his cell was working, but very feebly.

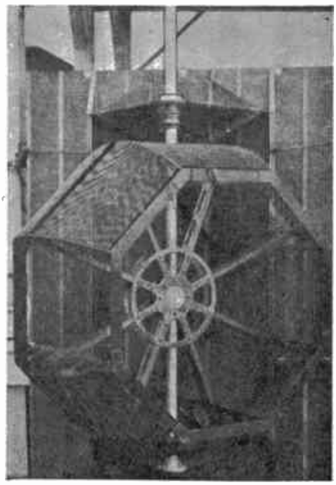
The next day, he tried in vain to find out from the teacher how Volta had tested the passage of the electric current which he had made. Miss Ferguson knew no more. She remembered the story of the discovery, and that was all. Hugh spent that afternoon trying to charge his Leyden Jar with current from his home-made Voltaic Cell, but failed entirely.

The last day of school came, and, on the boy's earnest request, Wat Burke agreed to take him with them to Foljambeville to see the teacher off. Hugh was profoundly depressed, for it was clear that Miss Ferguson would never return to a place where she had suffered so much from the mischief and ill-will of



The radio room of the U. S. Navy's big dirigible, showing the transmitting apparatus and the receiving loop aerial.

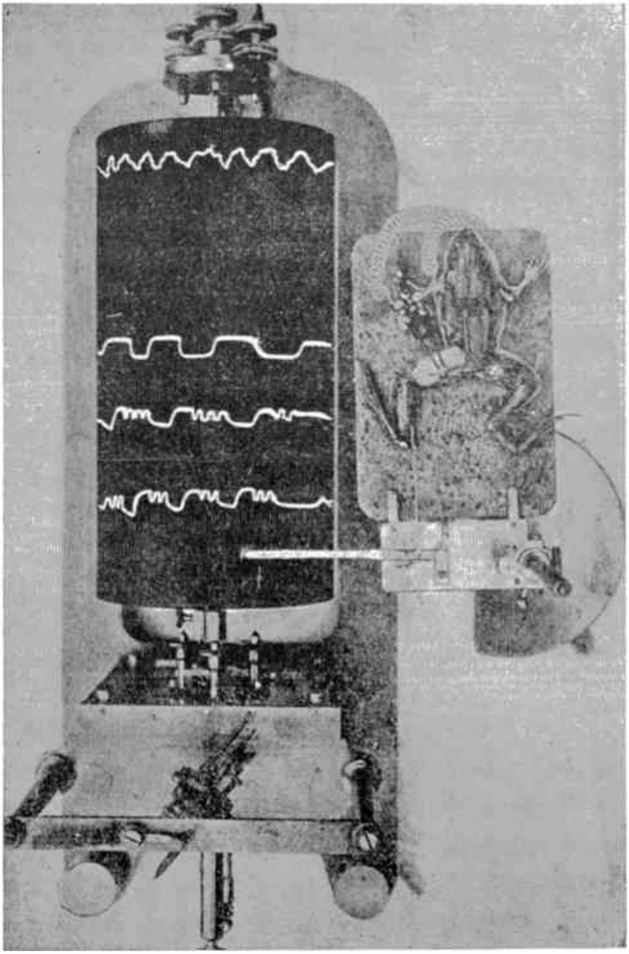
The Radio Compass.



The Directional Loop.

Courtesy of Radio News.

THE WIRELESS OUTFIT WHICH SAVED THE SHENANDOAH WHEN SHE WAS BLOWN ADRIFT IN A VIOLENT STORM.



Receiving Eiffel Tower Time Signals with a Frog's Leg.

The revolving drum covered with smoked paper is shown at the left. Alternating current oscillations received over the aerial were passed through the nerve of a dead frog's leg, and the resulting contraction of the muscle moved the lever which recorded the signals on the smoked paper.

the Ireton boys, and the lad realized how much he had gained from her sympathetic help.

They arrived at the station some little time before the train was due, and, for the first time in his life, Hugh saw the telegraph instruments in the dispatcher's office. He was fascinated by them. He noted the little coils of wire, the shining brass——

"Miss Ferguson!" he cried in great excitement. "Isn't that electricity?"

"Yes, that's the telegraph," she said.

"How does it work?"

The girl looked at him with a smile, and then tapped on the window.

The operator opened it.

"I'm sorry to trouble you," said she, "but do you suppose this boy could just take a look at your instruments? He's simply wild on electricity, and he's been experimenting all by himself in the mountains. I've tried to teach him all I can, but I know very little."

"Sure, Miss! I'll tell him what I know, ef he wants to learn. Come in!"

He gave her the only chair in the place and turned promptly to the boy:

"What do yo' know about telegraphy?"

"Nothin', sir."

"H'm, that's not much to start on. Do yo' know what an electric battery is?"

"Oh, yes, I know that! It's two metal plates in an acid solution, which produce an electric current; no, that's a cell. A battery is a lot o' cells together."

"Wa'al! An' do yo' know that a wire connectin' the two poles of a battery makes a circuit?"

Hugh nodded.

"I've done that, myself."

"So! If yo've got that much in yo'r head, then, the telegraph ain't so hard to understand. Suppose I have a battery here, an' the wire from one pole of it comes up through my table here, goes on to Asheville, an' then comes all the way back through my table to connect with the other pole of the battery, yo' can see that I've got a circuit which includes the station at Asheville, ain't I?"

"Of course."

"Next thing! If the earth was a good conductor—which it is—and that same circuit wire was grounded at this station an' at the Asheville station, the earth would act as a return for the current, wouldn't it?"

"I suppose it would," agreed Hugh, but a little doubtfully, for this idea was new.

"Yo' get that? Good! Now, suppose that wire or circuit was led around some apparatus on my table here, and around the same kind of apparatus at Asheville, and supposing I had some way o' startin' and stoppin' the flow o' the current—or makin' an' breakin' the circuit, as we call it—the current would be started an' stopped at Asheville in jest the same way as here, eh?"

"It couldn't help but be," declared Hugh, who was beginning to understand.

"Yo're on, eh? Now, suppose I let that current flow for a tenth of second, the time to tap yo'r finger on a table—which we call a 'dot'—or for three-tenths of a second—which we call a 'dash'—it's a cinch that I can make a series o' dots an' dashes that the other fellow in Asheville can understand, provided he has my code."

"That's so."

"Wa'al, that's telegraphy! All the rest of it is jest apparatus so's I can send the signal better, an' so's the other fellow can read it better. That means puttin' in a relay, or local battery circuit, to double up the strength o' distant signals; an electromagnet sounder, like this one, to make the signals easier to see an' hear; as well as special stuff for railroad work, or duplex work, which yo' don't need to worry about."

"An' that current, just from a battery, can go any distance?"

"Far as yo' like! Round the world, if yo' want it to, by usin' relays, like I said."

"Could I send signals with a battery current from Ants'-Hole Creek to Locustboro?"

"Whar's Locustboro?"

"It's in the mountains beyond Murphy. That's where I live," explained Miss Ferguson, smiling.

The operator scratched his head perplexedly, and opened the door of his office as the train whistled in the distance.

"As for telegraphin' from Ants'-Hole Creek as far as here," he said, "thar's nothin' to stop yo' but spending a few thousand dollars to string a wire, an', for Locustboro, a few thousand dollars more."

"I'm afraid that puts it out of the question, Hugh," put in the teacher gently. "You'll have to give up the idea."

The telegraph operator caught the look of sudden disappointment in the lad's face, and quickly grasped the note of tragedy. He was cove-bred, himself, and knew how a crash of hopes might wreck a mountain boy's ambition.

"Yo' don't have to give up!" said he. "Learn wireless! Telegraph without any wires!"

Hugh's response was quick and eager.

"How's that done?"

"Search me!" came the reply. "When I first started poundin' a key, wireless hadn't been heard of. But I know it can be done."

The train came rolling into the station with a grinding of brakes, and the teacher hurried along the platform, the boy carrying her suit-case.

"Some o' these days, Miss Ferguson," he said, as he handed her bag to her, "I'll ha' learned to say 'Thank You' by wireless—but I don't reckon I'll ever learn it well enough to be able to say all yo've done fo' me!"

CHAPTER V

THE PATH TO FAME

"JUDGIN' from what yo've been tellin' me," remarked Jed Bladen, the telegraph operator, after the train had gone and the two had settled down to a steady talk, "yo've been missin' out in yo'r experiments one o' the most important things in electricity."

"What's that, Mr. Bladen?"

"Magnets an' magnetism."

"I didn't have any to experiment with!" came the protest.

"Why didn't yo' make one?"

"How make one? Great-grandfather's Book says a magnet is a queer kind of iron comin' from Magnesia, somewhere in Asia Minor—wherever that is—an' called the magnes-stone."

The operator nodded.

"So it did, originally, but that's a long time back. Yo'r ancestor was talkin' about natural magnets. Of course, he couldn't know any other kind, I'd forgot that. Is that all he said?"

"No. He wrote that the magnes-stone attracts other pieces of metal, mainly iron, though he denied that it was strong enough to pull the nails out of ships, like the old legends tell. He said, too, that sailors put it in a box to steer by, because it always points north and south. They called it the lodestone."

"That's true enough, as far as it goes, but we've gone ahead a long way since the lodestone was discovered. Modern electrical work needs magnets an' needs 'em badly. So, nowadays, we make 'em. The most important kind for yo' to know about, if yo' really are in earnest about wireless ——"

Hugh nodded violently.

"—is the electromagnet. That's the boss of 'em all!"

"I didn't know that electricity had anything to do with magnets!"

Bladen grinned.

"Seems queer to hear any one sayin' that, nowadays, but ef yo' ain't never learned, I s'pose it ain't so surprisin'. After all, it ain't such a great while back that folks did find out about it.

"It was in 1820 that a fellow called Oersted, a professor in Denmark, first tumbled to the idea that electricity an' magnetism are pretty much the same thing. He was playin' around with a Voltaic Cell, somethin' like yours, Hugh, tryin' to find out if zinc and silver worked better than zinc and copper.

"On the same table whar he was workin', he had a compass needle, very delicately poised, for it was thunder-storm weather an' he wanted to see if the magnetic needle made any deflections durin' a storm. Do yo' know what a compass needle is?"

"I've never seen one, but isn't that what my book says always points north an' south?"

"Correct. Tell me, why does it point that way?"

Hugh puzzled for a moment, and then had to admit his ignorance.

"Because the earth's a permanent magnet," the operator explained. "Although it's nearly round, it has a north pole an' a south pole; call it a positive pole and a negative pole, ef that makes it easier fo' yo' to understand. A small magnet turns north an' south because the earth's lines of magnetic force run that way.

"Now the poles of a magnet," he went on, "behave jest like the signs of electricity do—like poles repel, unlike poles attract. That way, ef yo' bring the north pole of a strong magnet near the north pole of a feeble one, like a needle, the magnetic repulsion'll shove it away, that is, the needle'll stop pointin' to the magnetic north."

"You mean it's pushed off its line of centre, just like a pith ball is pushed away from its proper line of hanging down?" Hugh queried.

"That's it to a T!" agreed Bladen. "Now, listen to what happened:

"After he'd got through experimentin' wi' the Voltaic Cell, Oersted shoved it across the table, close to whar the compass needle was standin', an' got ready to get busy wi' somethin' else. First thing he knew, he noticed that the magnetic compass needle wobbled a bit, an' then slewed part way round.

"'Great snakes!' he must ha' said to himself, 'what's happenin' to that needle? The North Pole can't ha' changed places suddenly, that way!'

"He took the cell away, so's to look at the compass closer, an' the needle swung back to its proper place, pointin' north. He then put the cell close up again, an' zip! off went the needle to the other side!

"For a minute Oersted scarcely understood what he'd got hold of, then he caught on. He realized, all of a sudden, that he'd made a big scientific discovery. He'd found out that an electric current could deflect the magnetic needle. Since he knew that a strong magnet would do the same thing, the Danish professor was quick to spot the idea that the two forces might be alike; the same year, Arago, a French astronomer, proved the idea true. Get that?"

"You bet!" declared Hugh, quite at his ease. The operator's slangy explanation was a thousand-fold easier for him to understand than either Miss Ferguson's precise phrasing or Dr. Cameron's difficult talk about measurements.

"Well, the idea that the old boy in Denmark got a hold of, just a century ago," the operator continued, "is used right along in practical electricity to-day. What's called the 'galvanometer,' which is an instrument for measurin' electric currents, is, in its simplest form, nothin' but a magnetic needle suspended in the middle of a spiral o' wire. If a current is sent through the wire the needle'll turn away from the north in the direction o' the current. The stronger the current, the more the needle'll turn.

"They make galvanometers which are durn exact, nowadays, I'm tellin' yo'! A bit o' watch-spring, a quarter of an inch long, is used for the needle, an' a mirror not much bigger than the head of a pin is fixed on it. This mirror reflects a directed ray of light on to a scale a yard away, so that, if the watch-spring needle moves a hair's breadth, the spot of light reflected from the mirror travels along the scale, an' the observer watches the changes on the scale through a magnifying lens.

"Thar's some galvanometers so sensitive that they can show an electric current o' less'n one ten-thousand-millionth of an ampere! They can be made to measure powerful currents, too, heavy enough to electrocute an elephant!"

"Then, with a galvanometer," put in Hugh, "I could find out just how much current I've got flowin' in that Voltaic Cell I made o' tin an' charcoal?"

"Sure yo' could! An' a rough galvanometer's a cinch to make.[1]

"To go on," he continued, "Oersted was some smart. He figured, right away, that ef an electric current can affect a magnetic needle, in the same fashion that a magnet does, he ought to be able to make a magnet by usin' the electric current.

"So he took his Voltaic Cell again, coiled the wire which led from one pole to the other in a spiral—something like a corkscrew—an' hung a needle by a thread o' silk in the middle o' this spiral. As soon as he turned the current on, the steel needle was magnetized."

[1] For a handy lad who wishes to learn exactly how to make all such electrical devices, and, indeed, for all simple constructional work of this character, no better book has ever been published than "The Boy Electrician," by Alfred P. Morgan (Lothrop, Lee & Shepard Co.).—F. R-W.

"Couldn't I do that by chargin' my Leyden Jar, puttin' a spiral wire from pole to pole, an' hanging a needle in it?"

"Yo'r battery'd work better."

"Why?"

"Because the discharge from yo'r Leyden Jar is what's called an alternatin' current, that is, it jumps backward an' forward; yo'r battery gives a continuous or direct current, passin' through the solution from zinc to copper, an' along the wire from copper to zinc, goin' round an' round. You'd oughter be able to see that! Fo' makin' a magnet, continuous or direct current is better'n alternatin' current. Yo'll have to learn a lot about the differences between currents, by 'n' by, ef yo're goin' to take up wireless.

"Wa'al, Oersted went on a bit farther. He tried puttin' a lot o' different things in the middle o' the spiral o' wire; some o' them worked well an' others didn't.

"At last he tried a bar o' soft iron. Thar, he struck something quite different. It had taken quite a little time for the flowin' current thoroughly to magnetize a bar o' steel, but, once magnetized, it stayed that way. The bar o' soft iron was magnetized the very instant the current started, but lost all its magnetism the very second that the current stopped.

"That trick of Oersted's is used a lot to-day. I've got electromagnets thar on my table, handlin' the telegraph relay an' operatin' the sounder. Those are small ones. But the same scheme can work big things, too. In a good many o' the foundries an' metal-workin' plants o' the United States, when they want to pick up a bit o' metal weighin' several tons, they do it with an electromagnet."

"What?"

"It's a fact! They take a large bar of soft iron, or, more generally, a bundle of several hundred soft iron rods, an' bind 'em together by a wire with maybe as much as ten thousand turns. A strong direct current is sent rushin' through this wire, an', right away, all those soft iron rods become magnetized simultaneously. They'll stay that way just as long as the current flows.

"That makes a whopper of a magnet!

"When the foreman o' the gang wants to use it, the electromagnet is run out on an overhead crane until it's jest above the piece to be lifted, an' then lowered gradually. As soon as it's touchin' the metal to be lifted, the current is turned on, an' the block, weighin' a ton or more, 'll clamp to that magnet jest like the tobacco-ash stuck to yo'r Dad's amber-tipped pipe. I've seen locomotives lifted by an electromagnet! That'll give yo' an idea of what it can do!"

The boy nodded. The fact was amazing, but the principle was easy. If a small electrical force, acting magnetically, could lift a small thing, a large force could move a large thing.

"So far, so good. Now, thar's the other side o' the discovery," the operator went on. "An English scientist, called Faraday, when repeatin' Oersted's experiments an' elaboratin' 'em, figured that all electric currents must create an area of magnetic strain around 'em an' declared that if the movement of the electric current could make a magnet, the movement of a magnet ought to be able to make an electric current."

"What's that?"

Bladen repeated the phrase, and Hugh considered it carefully, word by word.

"An' can it?" he asked.

"It not only can, but it does. If yo' take a coil o' wire—not connected with a battery or anything—an' hang a magnet in the middle of it, so's the magnet can swing backward an' fo'ward, yo'll find that with every swing fo'ward an' back it'll start an electric current in the wire, an' the current'll flow in reversed directions, contrary to the swing.

"It's these two discoveries, Hugh, which have made electricity the all-useful thing it is to-day. Electric lightin', electric heatin', electric power for railroads an' tram-lines, an' a host of other things besides, are jest machinery applications o' the ideas o' Faraday an' Oersted."

"But aren't such machines right complicated?"

"They look worse'n they are. Once yo' get the principles down, yo' can understand 'em all, easy. An' ef yo're ever goin' to do anything wi' wireless, boy, yo'll have to tackle the whys an' the hows of electromagnetic machines. Have yo' got time fo' me to tell yo' somethin' about 'em, now?"

Hugh looked out of the window.

"Wat Burke's buggy isn't hitched up, yet," he said. "I reckon he's still in the store."

"Yo're better off here, listenin' to a bit o' science, 'n hearin' a lot o' dubs chewin' the rag about politics in the store, there! I don't know how much yo'll understand at that, ef I do try an' tell yo'," he went on, "but maybe some of it'll stick. Jest listen fo' all yo're worth!

"Thar's two different kinds o' electrical ma-

chinery, an' only two. The first kind converts mechanical power into electrical power, an' every machine o' that kind is called a 'generator.' It can get its first power impulse anywhere, from a steam engine, a gasoline engine, a water-wheel, horse-power, or even shoulder-grease. This last ain't to be laughed at, either. Right to-day, in the U. S. Army, the Signal Corps has worked out a wireless set which a man can carry on his back, an' the power which drives the generator is a crank, like that thing for roastin' peanuts that Italian Tony has thar on the corner.

"The other kind of electrical machine does jest the opposite. It converts electrical power into mechanical power, an' any such machine is called a motor. There's a heap o' varieties, but all wi' the same object. In electric automobiles, to take a simple case, a motor takes current from storage batteries an' turns it into mechanical power to turn the wheels an' drive the car.

"Maybe, a little later yo'll learn about induction coils an' transformers, but yo' don't want to think o' them as machines. They're electrical apparatus, an' their action is easy enough to understand when you get hold o' the principles of electromagnetic machinery, or dynamos, a motor bein' a dynamo reversed. Yo're clear, so far, eh?"

"I've got that, all right, Mr. Bladen."

"Then we'll go on. Probably yo've noticed that electricity works at a distance. Yo've seen that when yo'r electrified glass rod is brought near a hangin' pith ball, the ball begins to move afore yo've actually touched it. That shows thar's an influence spreadin' out from the rod. To make it easy, s'pose we call that region of attraction or repulsion—an 'electric field.' It's the same way with a wire—or any conductor—when an electric current is passin' through it; thar's an electric field around it, or a spreadin'-out of electricity from it. Get that fact solid in yo'r head.

"Next: magnetism works at a distance, too. Like poles repel, but they don't actually have to touch. Oersted didn't touch the compass needle with the wires from his Voltaic Cell, he only brought 'em close.

"Like fashion, in addition to the 'electric field,' which we'd do better to call 'lines of electric force,' a conductor wi' a current flowin' through it sets up a 'magnetic field' as well, and the 'lines o' magnetic force' (at right angles to those of electric force) keep spreadin' out, too. The two of 'em, combined, make it possible to send out and to receive wireless waves.

"But we're driftin' away from what I was goin' to say 'bout electromagnetic machinery! Yo' sit tight an' listen, for it's the in'ards o' the whole thing:

"Yo' can make a generator or a motor in two ways: either by revolvin' a magnetic field in an electric circuit, or by revolvin' an electric circuit in a magnetic field. The principle is jest this: whenever a conductor is moved across a magnetic field, an electromotive force is set up, or induced, in the conductor."

"I don't quite get that," put in Hugh.

"Don't get what?"

"That idea of something revolvin' in a magnetic field."

"Yo' can't? Get yo' head to workin'! The thing's easy enough to understand. I showed yo' afore that ef a magnet swings backward an' forward in a coil o' wire, it starts an electric current in the wire."

"Yes, I see that."

"Then what's worryin' yo'? I'm only turnin' the back-and-forward motion o' the swing into rotary motion!"

"Ah! Now I get it!" declared the boy.

Hugh's mind went back to the early days when he had made his piston-and-cylinder action from the rotary action of his water-wheel. This was only a reversal of the process.

"Here, I'll try an' make it easier fo' yo'," the operator went on, "fo' ef yo' don't get this point clear in yo'r head, to start with, yo'll be a fool at electric machinery all yo'r days.

"Suppose yo' take a small barrel hoop, of iron, rememberin' that iron is a conductor. Make two holes in the hoop itself, jest opposite each other. Now, hang up the hoop by a rope, first wrappin' a bit o' rubber from an old gum-shoe around the hoop where yo're goin' to tie the rope, in order to insulate it, rubber bein' a non-conductor.

"Cut a thin, round stick an' shove it through the two holes in the hoop, leavin' play so's the stick can turn round easily. Then fasten to the stick, at the centre o' the circle o' the hoop, an' at right angles to it, a light steel bar which yo've already magnetized like I've told yo', the bar bein' long enough jest to graze the hoop, but not to touch. That way, while the bar itself doesn't touch the hoop, the invisible lines o' the magnetic field, which project beyond the end o' the bar, do touch it. See that?"

"I suppose so," said Hugh, dubiously, for this question of "invisible lines" still puzzled him.

"Yo'll have to learn to see it! Now, ef yo' start to turn that stick, yo' turn the magnet with it. When the ends o' the magnet come near the hoop, the lines o' magnetic force cross that hoop, or conductor, an', as they're movin', they'll set up an induced electric current in the hoop." He repeated. "The lines of magnetic force, carried round by the magnet, are cut by the stationary conductor."

"Say that again, please," demanded Hugh.

Bladen repeated his whole illustration, gesturing with his hands to make the explanation clearer.

"What's more," he went on, "yo'd oughter to be able to see that it would be the same thing if yo' fixed the magnet stationary—say by nailin' the projectin' end o' the stick to a table, an' then set the hoop to whirlin' around it. The hoop'd cut the lines o' the magnetic field in the same way, an' a current'd get started in it."

Hugh nodded, but it was more a mere understanding of the words than a thorough grasping of the subject. The telegraph operator cudgelled his brains for some still more simple explanation. Then his eyes lightened.

"Look here, Hugh!"

He took a wooden match from a match-box and a common pin from a couple of train-sheets which he had pinned together. Through the match, near the end of it, he stuck the pin.

"Thar's yo'r magnet, say!"

Then he tied the two ends of a piece of string to the thumb and forefinger of his left hand, leaving the loop hanging. This done, he raised his left hand, curving the forefinger and thumb into a circle, but not quite touching. Picking up the match with his right hand, he slipped it between the tips of his left forefinger and thumb, so that the pin came in the middle of the circle, and commenced to revolve the match slowly.

Hugh jumped at the idea, instantly.

"Now I get you! The finger and thumb are the barrel hoop, or the conductor, an' the string is a wire leadin' to some apparatus to be worked; the pin is the magnet, an' the match a drivin'-rod to turn it with. Is that it?"

"Exact!"

Then the operator held the match steady, and slowly turned his left wrist as far as it would go.

"I see that, too, now," exclaimed the boy. "It's the same idea, exactly, only workin' the other way, the conductor doin' the turnin'. I'll make a big one, like that, when I get home."

"Yo'd better make several different kinds," Bladen advised. "Have yo'r magnets outside an' the conductor turnin' inside, too, for another pattern. Thar's no way o' learnin' like to doin' the thing yo'rself, an' ef you say that Doc Cameron has promised yo' a proper battery, yo'll have current enough to make all the magnets yo' want.

"But that ain't all thar is to it, yet! Current has direction. So has magnetism. I'll give yo' a simple rule to remember them by: If yo' grip a wire or conductor with yo'r right hand—yo'r right hand, remember!—the thumb pointin' in the direction o' the current flow, the curve o' yo'r fingers holdin' the wire'll show the direction o' the magnetic field."

He picked up his fountain pen and held it in his right fist, the nib outward. Then he turned his wrist, pointing the nib to his nose, the thumb toward it.

"Ef yo'll notice," he said, "the direction o' the fingers, from tip to palm, is clockwise, that is, if yo' follow the line round, yo'll be travellin' in the same direction as the hands of a clock. Thar's similar rules to show the direction of induced current an' of the motion of a conductor when the magnetic field is stationary, but yo'd better not confuse yo'r brain with 'em, now.

"Jest keep in yo' head the reversal rule and the 'right-hand rule' fo' direction, an' then we can begin to see what happened in the case o' the barrel hoop an' the bar."

He picked up the match and pin again, moving them, as before, in the little circle made by the left thumb and forefinger.

"Let's say the north pole o' yo'r bar is at the top o' yo'r barrel hoop. It's turning left-handedly, or counter-clockwise. Consequently, by reversal, the north pole o' the bar sends a current toward the right along the hoop. The south pole, which is at the bottom of the hoop, sends the current to the left. Since the hoop is round, leftward at the bottom is the same in direction as rightward at the top; in other words, the current is headed clockwise.

"The bar goes on turnin'—always at right angles to the hoop, remember!" He illustrated with the match and the pin. "As it makes a half-turn, the south pole comes to the top an' the north to the bottom. The lines of magnetic direction have reversed, though the motion of the bar is the same an' though the hoop is stationary. This flop-over changes the direction o' the electromotive force, an' now the current in the hoop flows leftward at the top an' rightward at the bottom; in other words, it goes counter-clockwise."

He handed the match and pin to Hugh, bidding him repeat the experiment himself.

"Since the current alternates from one direction to the other," he continued, "it's called by us fellows an alternatin' current, while yo'r Voltaic Cell current, which goes always in the same direction, is called a 'direct' current. Yo' can see fo' yo'rself that an alternatin' current has really four parts to it: a moment o' rest while the bar is comin' up an' afore the clockwise current starts, the clockwise push or impulse, another moment o' rest while the bar is goin' down an' then a counter-clockwise push or impulse. Each rest an' impulse together is called an 'alteration,' an' the four parts together, bringin' the revolvin' bar back to its first position, is called a 'cycle.'

"That's the simplest kind of alternatin' generator or alternator (revolving field type). Yo'r fingers have supplied the mechanical energy, an' the cutting o' the lines o' the magnetic field as a result of that energy have been transformed into induced alternatin' electrical current. Yo' could do it equally well by revolvin' a loop of wire between the poles of a horseshoe-shaped permanent magnet or electromagnet (revolving armature type). By puttin' in a commutator, which is a device consistin' o' two half-cylinders connected to the revolvin' loop o' wire an' touched at each half-revolution by stationary metal brushes, the alternatin' current generator is turned into a direct current generator. Sometime, this winter, if yo' like, I'll show yo' how that's done.

"Now work the same thing backward:

"Ef yo' take current from yo'r Voltaic Cell an' put it in circuit through a loop o' wire which lies in a strong magnetic field, the inherent force o' push in the lines o' magnetic force (through changes in linkings) will set the loop revolvin'. An' thar's yo'r electric motor! Simple enough, eh?"

"You call that simple!" blurted out Hugh, his eyes nearly popping out of his head. "Not me! I'm just runnin' behind in the dust."

"Ef yo' get to work on it wi' yo'r fingers, yo' won't find it so bad. It's only when yo' hear electrical contraptions described, or yo' read about 'em, that they seem hard to understand. Once make a little electric motor o' yo'r own, an' the biggest one'll seem like pie!

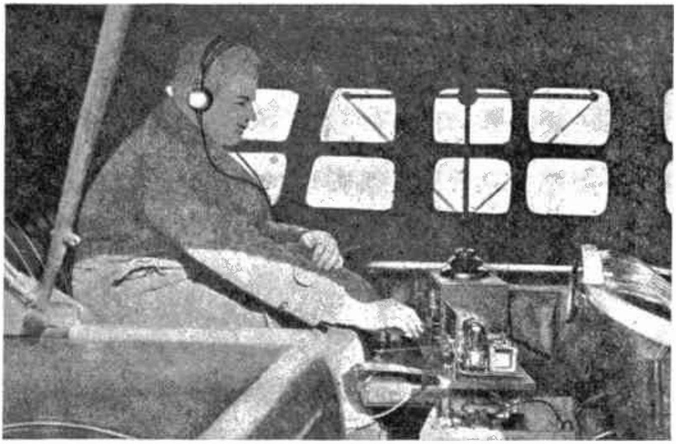
"Notice, though, 'most all these devices depend for their action on the influence o' the magnetic field, on magnetic induction. Pretty much all electrical machinery is electromagnetic. But, befo' goin' on any farther, boy, I want yo' to remember that magnetic induction can an' does exist without either a permanent magnet or an electromagnet."

"Jumping cats! It gets worse an' worse!" declared Hugh, who felt himself sinking in this sea of information.

"Don't let yo'self get woozy!" the operator snapped, though he realized that he had been putting a good deal of strain on the mountain boy's mind. "Yo're over the worst part o' the road. But what I'm goin' to tell yo', now, is important. It's this:

"Thar's always a magnetic field about an electric current. If two circuits are close together, an' parallel, the action o' startin' or stoppin' a current in one circuit will induce a current in the other. When the excitin' current steadies down, the induced current fades out. Yo' can see, though, that with an alternatin' current, which starts, stops, an' starts again thousands o' times in a second, what amounts to a practically constant current can be set up by induction in a circuit which hasn't any excitin' source of its own.

"Likewise, if a faint alternatin' current be received by a circuit which hasn't any excitin' source o' current, it can be picked up, by magnetic induc-



Courtesy of QST

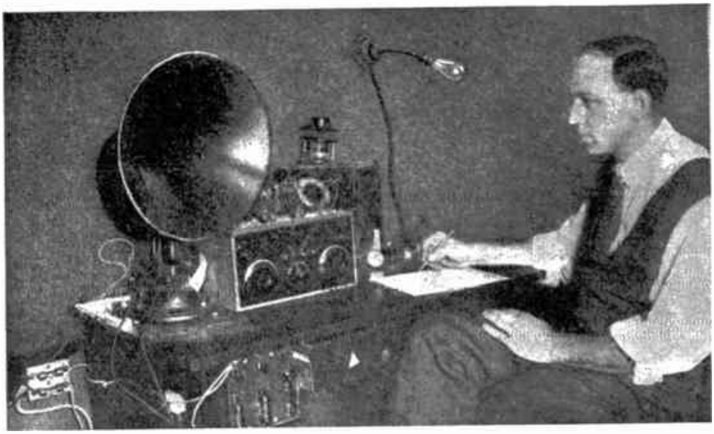
Trailing the "squeals" and "howls," by a portable wireless set in an automobile; the local electric light company was found responsible, and the wires re-routed.

Courtesy of Radio News.

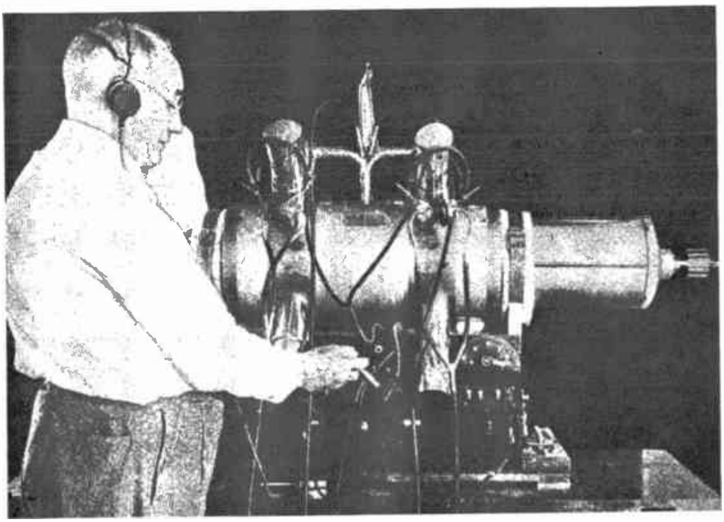
Testing the "rattles" and the "buzzes" made by an elevated electric train.

Registering the "thumps" and "yawps" emanating from a high power generator.

Wireless Amateurs Engaged in Making the Air Clearer for All Radio-Users by Discovering the Causes of Local Interference.



John L. Reinartz, inventor of the Reinartz Receiver and Modulascope.



W. J. Scott, inventor of the claraphone, devised both on acoustical and wireless principles.

CHAMPIONS IN THE FIGHT AGAINST ATMOSPHERIC DISTURBANCES KNOWN AS "STATIC."

tion, in a tuned circuit with a strong local current, an' magnified as much as yo' like."

He leaned forward and put his hand on Hugh's shoulder, impressively.

"That's how wireless works!"

The operator paused a moment, to let this sink in, and went on:

"So much for principles, now for practice!

"Electromagnetic machinery generally is operated at high speeds. Let's see how that works out. S'pose we go back to the simple alternator that we began with. We said that in each cycle the current gets two impulses. If a magnet rotates inside a conductor, or if a conductor rotates between the poles of a magnet—it doesn't matter which—at a speed of 120 revolutions per minute, it will have made 2 cycles per second an' given 4 impulses in the conductin' circuit, alternatin' first in one direction, then in the other."

"That's clear!" agreed Hugh, glad to be on firmer ground once more.

"Now, s'pose yo' wanted to get yo'r cycles quicker, more of 'em to a second—greater 'frequency,' as that is called—how'd yo' go ahead about it?"

"I'd turn the revolving part quicker."

"S'pose yo' wanted a frequency of 60 cycles a second, which is an ordinary commercial frequency?"

"I'd have to turn at 3,600 revolutions a minute," the boy replied, after a moment's figuring.

"Which would be too fast for safety in a big machine of that sort. She might fly to bits. But s'pose you wanted a frequency of 500 cycles to a second, which is ordinary audio frequency for the telephone."

"Meanin' 30,000 revolutions per minute? I don't believe you could do it."

"Yet it's done, right along!"

"How?"

"Can't yo' figure out a way?"

Hugh thought for a while and then shook his head despairingly.

"Yo' sure ain't born to be a mechanic," declared Bladen reprovingly. "I'll show yo'. S'pose, instead o' havin' one bar revolvin' inside yo'r barrel hoop, yo' had two!" He stuck a second pin in the wooden match, crossing the one which was already there. "Then, without increasin' the revolutions, yo'd have twice as many cycles, eh?"

"Sure! Why didn't I think o' that?"

"S'pose yo' had 10 magnets, or even 100. Then yo'd have a hundred times as many cycles. With yo'r speed o' 120 revolutions per minute, a multipolar alternator (north and south poles bein' alternated with each magnet) would give yo' 200 cycles a second. That's already somethin'!"

The boy nodded.

"So far, we've only talked o' the multiplication o' magnets, whether they're in the stationary part ('stator'), or in the rotatin' part ('rotor'). But it's just as easy to multiply the conductors in the armature, whether it's stator or rotor. Yo' could put 100 coils or windin's for conductors in the armature, so's yo'r 100 field magnets would sweep by 100 conductors in each revolution. That would give yo' 20,000 cycles per second on 120 revolutions per minute.

"That's jest theory, to give yo' an idea, Hugh. There'd be big constructional difficulties in making such a machine. It's much easier to increase the speed of revolutions an' to decrease the complication of magnets and armature conductors.[1] Still,

[1] The field radio pack set, designed by the U. S. Signal Corps to be carried on the back, operates by means of a crank shaft driven by hand. The crank is turned at a speed of 33 revolutions per minute, and, being geared at 1 to 100, the generators make 3,300 revolutions per minute. The alternator is of the revolving armature type, and is a 500 cycle machine. The armature has 18 teeth for conductors and there are 18 field poles. The whole machine, which is thoroughly efficient, is less than six inches in diameter and scarcely four inches high.

I've heard that there are big radio high-frequency alternators with 300 field magnets and 300 conductors. The makin' of a machine such as those, taxes the highest human skill, an' thar ain't a hundred o' the finest electrical engineers livin' to-day that could either design or make one."

"But such machines must take a terrible lot o' power to drive!"

"They take a good bit, but that's one o' the queer things about electrical machinery. Yo' can multiply its powers in most amazin' fashion. Ef yo' know the tricks of it, yo' can start with almost nothin' an' build up an' up. Yo' can take a generator an' a motor an' then a generator, yo' can use all sorts o' things like symmetry an' resonance[1]—of which I don't know any more than the names—an' do most anything.

"Why, yo'r water-wheel, Hugh, in the hands of

[1] The marvellous Alexanderson high-frequency alternators, used by the U. S. Government for long-distance work, and such as are employed at New Brunswick, N. J., Tuckerton, N. J., Marion, Mass., and Port Jefferson, L. I., are rated at 200 kilowatts, generated at a frequency of 22,000 cycles per second on 2,170 revolutions per minute; the armature has 64 windings. In the most powerful station in the world, that of Ste. Assise, near Paris, the Bethenod alternators are triple-mounted on a single shaft—and are rated at 500 kilowatts. The Goldschmidt alternator works by electric resonance (a highly complicated principle) and reaches 48,000 cycles per second, but at the cost of over-high rotational speed. The Telefunken alternator (German) depends for its high frequency on a special step-up transformer which is a separate unit.

some one who knew just how to develop all its force electromagnetically, could produce power enough to give electric light to the whole of Ants'-Hole Creek. It's all in knowin' how."

"Could I get power enough out of that wheel to send signals by wireless?" queried Hugh, for the lighting of the creek valley was not a matter of any interest to him.

"Yo' could send 'em from here to Los Angeles!"

"Then I will! But it's Locustboro I want to reach."

The operator held up a warning finger.

"Hold yo'r horses, boy! Like I'm tellin' yo', the principles are easy, but the doin' ain't. Electricity is tricky, an', the minute yo' begin to deal wi' powerful currents, yo'll find trouble. Fo' one thing, every detail has got to be so plumb exact, an' thar ain't no way to get exactness without a pile o' figurin'. An', fo' another thing, all yo' material has got to be perfect. Some tiny thing yo'd never thought of will kick all yo'r best notions endways."

Hugh's face fell.

"I can learn to figure, I reckon," he said, "though it doesn't come easy to me, but about buyin' material?"

"I'd been thinkin' o' that."

The operator slid in his chair, reached under the table with his foot and poked out a small wooden box.

"I've a lot o' junk in thar," he said, "bits o' copper wire, screws, an old sounder with electromagnets on it still, a small induction coil, an' a heap o' scrap. Some of it's good enough, an' some ain't worth shucks. I've been intendin' to throw it away, fo' a year an' more, an' never took the trouble. Thar it stands, gatherin' dust an' dead flies. Yo' can have it, an' welcome, ef yo' want it; it's been thar ever since the railroad put in a new outfit, here. It's no use to the Company, but yo' might find some stuff yo' could use fo' experiment an' that yo' couldn't buy in this burg."

The boy's eyes glittered at the prize.

"It seems too much for me to take. You really don't want it yourself, Mr. Bladen?"

"Me? No! I've got all I want of electricity in my daily job."

Hugh promptly squatted on the floor, handling the pieces of apparatus, one by one, so absorbed in his treasure that he never heard a buggy drive up to the station.

"Hey, yo'," said the operator, "thar's Wat Burke callin'. Take the box along. An', any time yo're in town an' want to know anythin' that I can tell yo', hop in here! So long!"

He shook hands with the boy heartily and turned back to his work, leaving Hugh as dazed with the store of information he had received as with the boxful of antiquated telegraph apparatus and wiring which had been tossed aside and forgotten.

Although Wat Burke had not the faintest notion of any electrical question, Hugh could not resist talking to him, all the fourteen miles to Ants'-Hole Creek, of the things which he had learned from the telegraph operator.

So far as the moonshiner's understanding went of what was said to him, the boy might as well have been talking to the horse. He listened respectfully, however, and now and then made an exclamation or put in a question, to show a certain interest. Burke was really grateful to the boy for the electrical treatment given to his wife, and the lad's pluck in watching over the teacher during three cold winter nights had appealed to the moonshiner's sense of admiration. Furthermore, he knew that both Dr. Cameron and Miss Ferguson believed that the boy should be helped on in his scientific aspirations as much as possible, and he decided to play his share.

Burke's help took a practical turn. Next time he went to Foljambeville, he dropped in to see the telegraph operator.

"Yo' know that Cecil kid yo' were chinnin' to, t'other day?" he remarked.

"The one wi' the wireless bug? Yes. What about him?"

"I was thinkin' I'd like to give him a boost. He's been right good to my wife."

"Wa'al?"

"How about my givin' him a 'listenin'-in set'?"

He pulled a mail order catalogue from the pocket of his big fur coat.

"See, these people sell one!"

He put his finger on the advertisement.

Jed Bladen shook his finger in negation.

"I wouldn't ef I was yo', Wat Burke," he answered. "I had somethin' the same idee, an', knowin' ol' Doc Cameron is interested in the lad, I asked him. Doc said, no! His dope is that ef the youngster's ever goin' to amount to anything, he'll have to plough his own furrow. Givin' him something ready-made'll spoil him. He'd get dissatisfied wi' his own rough models an' might be apt to quit."

"Wa'al, what then?"

"Why not send him a radio magazine o' some sort? Thar's a lot of it he won't understand, but he'll get something out of each number. An' what he doesn't know'll make him think."

Burke slammed down a five-dollar bill on the table.

"Yo' find the right one an' subscribe, givin' the boy's address, an' tellin' the editor not to tell who's paid fo' it."

"Right, Burke, I'll put it through," agreed the operator, and, with the cordiality of partnership in a good deed, the two men separated.

When, the week following, the radio magazine arrived, addressed to him, Hugh was astounded. He wrote to Miss Ferguson, to the doctor and to the telegraph operator, thanking them and protesting at the same time. All denied that they had subscribed for the paper. The boy never thought of suspecting Burke.

True to her promise, Miss Ferguson wrote a weekly letter to the boy, giving him some simple sums in arithmetic and some still simpler problems in algebra. The lad was actually hungry for these, and worked at them with great zest. He did well enough in general, but he advanced very slowly.

Dr. Cameron had sent him the promised battery, and also a book on electricity. What was more, he came twice to see about Cram Ireton's leg—though the visits were not really necessary—and each time he spent an hour with Hugh, helping him to understand the book, and explaining to him the diagrams in his radio magazine.

The loss of school, the following winter, was not so serious a matter for Hugh as it might have been. He had learned to write with ease, and, what with his weekly lessons, the sending of letters and his experiments, his time was fully occupied. He managed to do a little hunting and trapping, and, in the early spring, he had a tidy package of furs to give to each of the friends who had helped him.

The text-book on electricity was more exciting to him than any story. No sooner did he grasp some principle that was told there, or understand the nature of some experiment, than he tried to put it into practice. This is a thing not uncommon among eager and interested boys, but Hugh was in a peculiar position. He had scarcely any of the material necessary for experimentation, he was not near any town where such material might be bought, and he had no money to buy such things with, even if he had been.

Nearly all his experiments, therefore, were carried out with barbed wire (from which he untwisted

the barbs with a pair of pliers), with bits of tin, iron, lead, and brass from old cartridges, with broken glass for insulation, with rusty nails, and, above all, with the various pieces of material that came from the telegraph operator's box, and which were used over and over again in a score of different ways.

Twice, in the winter, he took the twenty-eight-mile walk to Foljambeville, fourteen there and fourteen back, for a talk with Jed Bladen. He had decided to make a little dynamo for himself, and had run into a number of troubles. Still, he had succeeded, and though it coughed and spluttered a good deal and was as cranky as a mule in fly-time, it had served the purpose of teaching him the real difference between a generator and a motor, and between a direct-current and an alternating-current machine.

As the operator had predicted, problems which sounded incredibly difficult when described were easy to solve in practical fashion. The main trouble was in securing the careful finish which good electrical work demands, and many were the ingenious tricks devised by Hugh to secure results with unsuitable material and poor tools. The stead had become a regular electrical museum, for, on the doctor's advice, the boy had kept his most primitive models, in order that he might be able, later, to follow his own advance.

Toward spring he received a most extraordinary letter. It ran as follows:

"HUGH CECIL:

"DEAR SIR—We are informed by Dr. Cameron of Foljambeville that you are interested in wireless, and that you have constructed several pieces of electrical apparatus in a most original way. Such matters are of interest to our readers. If you should care to send us a short description of these devices, with a rough sketch of them, we should be glad to pay you at the rate of ten dollars an article for a series of four. We prefer that your articles should not be corrected by any other hand, as there is a value for the amateur in reading how such things have been done, in your own words.

"Trusting that you can favor us,

"Yours very truly,

"EDITOR, *The Radio Realm.*"

Hugh read this breathlessly.

"Dad!" he exclaimed. "Here's a man offers me forty dollars!"

The mountaineer tapped the ashes from his pipe on the table, as he had done a couple of years before, when Hugh had bidden him rub the amber mouthpiece on the sleeve of his coat.

"'Ta'n't for nothin' wrong, is it?"

"Why, Dad! Here, let me read you the letter!"

"It's reasonable enough," the mountaineer commented, when the lad had finished. "Thar a'n't any why-for yo' shouldn't write. Some one's got to fill the paper."

"But can I do it well enough?"

"I s'pose, ef the editor didn't want yo' to, he wouldn't have asked yo'!"

He smiled a slow smile.

"I reckon thar's goin' to be another 'Great-grandfather's Book' in the family, an' this one's goin' to be in print!"

CHAPTER VI

SAVED BY A SPARK

The appearance of Hugh's articles in the *Radio Realm* created a sensation on Ants'-Hole Creek, but one quite different from what their author had expected.

Aside from the boy himself, and a few children who had learned the rudiments under Miss Ferguson and the prior teacher, there were only three people in the valley who could read. These were Ireton, Burke, and "Millennial Joe," the latter being the local hedge-preacher, an old man who had invented a religion of his own. To each of these men the boy had sent copies of the magazines, partly from a natural pride in his work and partly because he hoped to secure the united approval of the valley folk in that way.

These three men duly showed the four issues of the magazine to all their friends and Hugh's articles were read out loud by one or the other to different groups of listeners. By the early autumn, every one on Ants'-Hole Creek had a fair idea of the boy's experiments, beginning with his water-wheel and ending with the very primitive wireless set which the lad was attempting to construct.

According to the opinions and comments of these three readers—who were the arbiters of thought in the creek valley—Hugh's articles received very different interpretations. These opinions were reflected in the minds of those who first heard of the boy's plans and hopes as seen through another man's eyes.

Those, for example, who learned of Hugh's efforts through the medium of Burke's reading were ready to join in the moonshiner's chant of praise. They showed friendliness and promised to help the lad in his projects as much as possible.

Those who fell under the influence of Ireton took an entirely different tack. They paid little heed to the mechanical interest of the articles and less to the psychology of the young writer, but they bitterly resented the publicity which had been given to their own backwardness and ignorance, as cove-dwellers. Hugh had not intentionally tried to expose this weakness, but, in explaining the straits and shifts to which he had been driven for material, and in describing—however lightly—the comments of the neighbors on his work, the poverty and the unprogressiveness of the cove had been revealed.

Far other, again, was the result produced by

Millennial Joe's reading of the articles. The narrow bigotry of this misguided man and the selfishness of his personally invented creed caused him to look on everything with an eye of suspicion and hate. Like many small-minded people, he tried to increase his own importance by giving a sinister aspect to what others had considered an innocent thing.

"Ef he likes to make a sawmill or a grindin'-mill by water power, let him go for an' do it!" declared Millennial Joe. "That's nateral enough! But I don't hold with electricity, noways. Lightnin' belongs up in the heavens, an' we ain't got no call for to try an' bring it down. It's sacrilege, that's what it is!"

Some of his hearers, who had visited the neighboring city and had seen electric lights, telephones and street-cars, protested at this, but the graybeard went on:

"As fo' this wireless, that's worse! It stands to reason," he declared dogmatically, "that ef thar ain't no wire runnin' from one place to another to slide a message along, somethin' else must carry it. Who carries it, that's what I want to know? Who carries it?"

He paused a moment, and then continued in his droning camp-meeting voice:

"The Good Book tells us that the air all round us, everywhar, is jest full of angels an' devils. Yo' can't see 'em, but they're thar! I reckon thar's more devils 'n angels, because—in a place like this creek, leastways—thar's more for 'em to do.

"This hyar wireless is a big chance fo' 'em. If messages are bein' carried through the air, who's doin' it? Are the angels likely to get busy wi' dance-music an' sech-like? No! It's the devils what are carryin' it. All that Hugh Cecil is doin' is to fill the air o' the creek fuller o' devils 'n it was afore!"

Absurd as this reasoning was, it found many adherents. The superstitious cove folk[1] believed in ghosts and spirits of every kind, and Millennial Joe's explanation gave them something they could understand, whereas the magazine references to waves, oscillations, etheric vibrations and the like, were utterly incomprehensible.

To make matters worse, Ireton was a religious

[1] Lest this should seem an exaggerated portrayal of the conditions found in cove valleys, the author wishes to state that, less than ten years ago, in a comparatively prosperous valley in North Carolina, where several of the farmers own automobiles, a bronze bust of a Roman gladiator, on the author's porch, was taken to be an idol. A committee of the citizens waited on the author, threatening him with punishment as an "idolater" if he did not leave the country at once. Only the showing of letters proving that he was a member of a Christian church, in good standing, prevented a very unpleasant incident.—F. R-W.

man of the fanatical type, though not of Millennial Joe's persuasion. His Puritan blood reacted quickly against anything that savored of the theatre, and, as ill-luck would have it, an article in one of those magazines described the success of a popular vaudeville star whose songs had been broadcasted by the WJAZ station, in Chicago. The article was illustrated by a photograph of the girl, in a sensational stage costume, and this picture was seized upon by Ireton as showing the corrupting possibilities of wireless.

The adverse influence of Millennial Joe and of Ireton soon began to be felt by Hugh. The favorable attitude toward his experiments which had been produced by the success of his electrical treatment of Mrs. Burke diminished little by little.

The more ignorant of the cove-dwellers, especially at Millennial Joe's Sunday afternoon meetings, began to murmur against the "wireless devils," and the old bigot did not neglect to fan the flame. He even hinted that Hugh's stead—like the old sinful cities of Sodom and Gomorrah—ought to be destroyed in the interest of righteousness.

Others of the community followed Ireton's lead, and, while admitting that radio might be a scientific fact, demanded what good purpose it could serve, aside from its use for ships at sea. They took especial objection to the broadcasting idea, and asked how decent people could be sure of hearing only decent things on their receivers if the air was going to be filled with silly messages, cheap jokes, third-rate songs, and undesired advertisements.

Burke bluntly took Ireton to task for his animosity and his narrow-mindedness, and the two men nearly came to blows. This did not help Hugh's work, but rather emphasized the sense of dissension. The Ireton boys found the current of popular favor swinging in their direction, and quickly sensed their advantage. Cram, who had been nursing his revenge, commenced to plot anew.

Ignoring all this hostility, Hugh continued with his experiments. He had plenty of material, now; more than he could use. Immediately after the publication of his articles, readers of the magazine from all parts of the country had sent him boxes of equipment. Many an amateur who had abandoned a simple set for a more complex one was glad to find a brother experimenter who could make use of his old apparatus.

The boy was eager to plunge in and construct a wireless set which really would produce results, especially one which would be strong enough to transmit as far as Miss Ferguson's home at Locustboro, but Dr. Cameron held him back.

"You haven't got scientific training enough to leapfrog into the middle of a subject like radio," he wrote. "You're young, you have the time to learn. Begin by constructing for yourself the outfits used by the pioneers of wireless: Hughes, Hertz, Branly, Lodge, Righi, and Marconi. Get hold of their first ideas, learn their mistakes, find out how they overcame them and observe how they perfected their apparatus, little by little. In that way you'll really understand the development of wireless, and even the most complicated modern outfit will have no surprises for you. Begin with Hertz. You can leave the earlier conduction and induction types of telegraphy alone."

The letter then proceeded to give a brief résumé of those earlier experiments, the first of which dates back more than a century ago. In 1795, Salva, an Italian, inventor of the electro-chemical telegraph, suggested the use of water, instead of wires, for his return circuit. In 1838, Steinheil, a German, pioneer of the electric telegraph, discovered that the earth has conductive power, and sent messages, through the ground, a distance of fifty-nine feet, without wires. In 1842, Morse, an American, inventor of the Morse Code, sent a telegraphic message through water a distance of one mile. In 1853, Lindsay, a Scotchman, increased this distance to two miles, and, what was more important, interested Preece in his experiments. Bonelli in Italy, Gintl in Austria, and Douat in France, also worked on the principles of wireless telegraphy by conduction.

The second great principle used in early wireless experiments was induction. Bell, a Scotch-American, inventor of the telephone, was the first, and, in 1866, he suggested that the deaf might hear by this means. Sacher in Austria, Dufour in France, and Edison in America also worked along this line. In 1879 Trowbridge, an American, suggested a means for telegraphing across the Atlantic without a cable, but, though the plan was theoretically feasible, its cost was prohibitive. Prof. Dolbear, of Tufts College, exhibited a wireless outfit at the Electrical Exhibition in Philadelphia in 1884; this was supposed to be an induction system, but Dolbear was really employing Hertzian waves without knowing it. Brown, Smith, and Edison-Gilliland, in 1881, 1883, and 1887, respectively, used the induction system in telegraphing without wires to moving trains.

The climax of all this work came in the success of Preece, the great English experimenter, who carried wireless by induction to its highest notch, employing it for shore-to-ship communication, adapting it for instant use on two occasions when short submarine cables had parted, and even establishing a commercial system therewith. The principle was sound for short spaces, but Preece himself declared that it was useless for long distances on account of the great lengths of wire needed—on either side of the gap to be crossed—for its successful working. Inductance was practically abandoned in 1899, since, two years before, Preece had been converted by Marconi to the third great type of wireless communication—wireless by radiation, better known as radio-telegraphy. Lately, however, the U. S. Bureau of Mines has taken up wireless by induction, again, for the use of rescue work underground.

Although the fact is often ignored, it was an American physicist, Joseph Henry, who was the first to announce, in 1842, that the discharge of a Leyden Jar is an oscillatory movement. In 1847, Von Helmholtz, the great German optical physicist, endorsed Henry's statement, and suggested that such oscillations must "disturb the atmosphere." In 1853, Lord Kelvin, an Englishman, worked out the mathematics of the problem. In 1859, Fedderson, also an

Faraday.

Henry.

Clerk Maxwell.

Crookes.

Morse.

Bell.

The Forerunners of Radio.

HERTZ.

BRANLY.

LODGE.

MARCONI.

FLEMING.

DE FOREST.

THE GENIUSES OF RADIO.

Englishman, showed how such oscillations could be photographed, although each oscillation takes only a fraction of a millionth of a second.

Such was the situation when, in 1863, J. Clerk Maxwell, a famous Irish mathematician and scientist, who had been developing Lord Kelvin's calculations on electric oscillations, advanced the theory that electricity travels through space by the medium of the ether, as does light. This theory assumed that the material universe lies in one all-pervading ether, and that if this medium be disturbed at any place, the disturbance is propagated to other places in the form of waves.

To express Clerk Maxwell's theory in simple terms: All forms of radiant energy are electromagnetic disturbances sent out through the air or other media in the form of electromagnetic waves, which are carried by the ether.

This theory lacked experimental proof, but, backed up as it was with a wealth of mathematical reasoning, it was the real beginning of radio. Von Helmholtz rightly declared Clerk Maxwell's conception to be "one of the most illumining discoveries that ever has come from the human mind."

Von Helmholtz, himself one of the great scientists of the nineteenth century, at once plunged into a study of electric oscillations in the light of this new theory. In 1871 he published his figures for the velocity of electromagnetic induction, and declared himself convinced of the truth of Clerk Maxwell's researches, but he was unable to devise any means of experimental proof. This was left for Hertz to accomplish.

Hertz, at the age of twenty-one, was a student in Berlin, in attendance on Von Helmholtz' lectures. The old physicist was struck by the young fellow's marked ability and by his capacity for original research, and urged his pupil to work on the Clerk Maxwell theory. In 1880 Hertz attracted European attention by his famous essay on "Electricity in Motion" and became Von Helmholtz' assistant the same year. In 1883 he went to Kiel, there to begin the researches which, five years later, enabled him to prove experimentally the character of the electromagnetic waves whose existence was forecast by Clerk Maxwell. He devised means for measuring their length and velocity and established their complete correspondence with the waves of light and heat. Thus Hertz brought to full fruition the work of Clerk Maxwell and their names must ever be bracketed together in this world-shaking discovery.

The death of Hertz, a few years later (while he was still quite young) robbed the new-born science of Radio of one of its two founders, and the death of Von Helmholtz, in the same year, necessarily turned the future of radio to other countries and other hands. Sir Oliver Lodge, in England, became the successor of Clerk Maxwell and Von Helmholtz in the realm of theory; Marconi, an Irish-Italian, became the successor of Hertz in practical experimentation, most of his work being done in Italy, England, and America, though Hughes had preceded him and had actually made a wireless set, which, unhappily, three prominent scientists decried, thus causing an abandonment of the experiments.

"Begin with Hertz!" Dr. Cameron had written to Hugh. This, then, was to be the starting point of the boy's work in the making and understanding of wireless.

The hostility to the young experimenter which had developed in Ants'-Hole Creek as a result of the famous magazine articles had brought father and son closer together. Burly Cecil, ever suspicious of his neighbors, had a wary eye for undesired intruders, and kept close guard over the stead. Moreover, he deliberately set himself to watch the boy's experiments, in the hope that some day he might begin to understand.

The lad's first task clearly was to make a Hertz oscillator, exactly similar to that one with which the first known radio waves were sent out (although, as is known now, electromagnetic waves were and are propagated by every electric discharge).

Since Hertz had for his special aim the experimental testing of Clerk Maxwell's theory, he had decided that a spark discharge would give him the variety of electric waves which would be the easiest to trace and to measure. The best spark was to be secured from a Leyden Jar or other condenser, high voltage being secured by the use of an induction coil.

Hertz used for his oscillator the principle of a Leyden plate, but he changed the usual form, so that, at first sight, his condenser did not look like a condenser at all. Instead of having the two metal plates near together, with a piece of thin glass between, as a dielectric, he reversed the situation completely. He put the condenser plates as far apart as possible, making them like two spades turned end-for-end, with handles together but not quite touching. Highly polished spark balls took the place of the hand-holds. For a dielectric, he had the air. These two spade-like plates were in a perfectly straight line, one to the other, and were mounted perpendicularly, as if the edges of the sides of the two plates were resting on a table.

The condenser plates were connected (at points along the rods leading to the spark balls, slightly different on each rod to secure irregularity and to facilitate the first oscillatory discharge) to the secondary winding of an induction coil. The primary winding of this coil was connected to a battery of Voltaic Cells, with an interrupter or vibrator and a manipulating key in the circuit.

Hugh had read very carefully all that his text-book had to tell about Hertz' work. He had studied, to the best of his ability, all the "hook-ups" or technical designs in the issues of his radio magazine. Most of these he had copied, in drawing, a score of times, first roughly and then with exact detail. After several months of this copying work he found himself able to follow even the most complicated hook-up design with far more ease than he could understand a written explanation.

At last, when all his parts were made and ready for assembling, the boy called his father to the stead to witness the putting together of a model of that very same oscillator with which Hertz had unlocked the gates of radio.

"You'd oughter be able to understand this contraption, Dad!" declared Hugh confidently. "It's easy as easy!"

"I've heard yo' say that about sech things afore," declared the mountaineer, "but my head don't work the way yo'rs does. I'm willin' to look an' listen, an' yo' can't ask mo'!"

"No, but I really can make this simple enough for you. Just watch!"

He reached down below the table and brought up four Voltaic Cells, which he proceeded to connect together, talking as he worked.

"I've explained these to you before, Dad, but, just to remind you, I'll repeat. These cells, here, produce a steady electric current because a chemical change gets started between the copper an' the zinc (in weak sulphuric acid) as soon as their tops are connected with a wire. The current goes through these two wires, out by the copper (positive pole), an' back by the zinc (negative pole). When the electrode plates aren't connected by the wire, that is, when there's a gap in the wire, the current stops."

He paused long enough to wire in a simple manipulating key, acting on a spring, like a telegraph key.

"That's what this is for. See, Dad, I wire it to the copper or positive pole of the battery. If I don't press it down, the spring holds it up; that leaves a gap in the circuit, an' the current stops. When I press it down, so that it makes a bridge to join the two wires together, the current flows."

"I'm followin'!" declared the mountaineer. "It's like a gate in a fence. When the gate's open, it's jest the same as ef thar wa'n't no fence at all, the cows'll come through; when the gate's closed, it's a part o' the fence."

Hugh smiled inwardly at the analogy, but saw that nothing would be gained by trying to be more explicit. Going on with his assembling, he held up a small cylinder.

"This is what's called an induction coil," said he. "Inside this tube of cardboard is a bundle of soft iron rods. On the outside of the cardboard I've wound about fifty turns of fairly thick wire, 1/25th of an inch in diameter; that's called the primary windin'.

"Notice, Dad, I connect the other battery wire—from the negative pole or zinc end of the last cell—to one end of this primary windin', the left-hand end. You can see for yourself that if I should join the key to the loose end of the primary windin', I'd have the circuit—or the fence, as you call it—made all round. The 'gate' would be closed, an' the current from the battery would go chasin' 'round all those turns of the primary windin'."

"I reckon so," agreed the mountaineer.

"I'm not goin' to connect it direct to the key, though," the boy went on, "an' I'm goin' to tell you why." He touched the iron core of the cylinder. "I've got a bundle of soft iron rods in here. Like I showed you, one time, in another experiment, Dad, soft iron is easily turned into a magnet by putting it inside a spiral of wire through which a current is passin'. This primary windin' is such a spiral. When the current goes through it, the iron becomes a magnet; when the current stops, the iron loses its magnetism."

Burly Cecil nodded, but it was clear that he was becoming confused.

Hugh took out his pocket-knife and, with a jerk, stuck it into the wooden table, so it vibrated back and forth.

"This knife-blade acts like a spring," he said, "an', bein' steel, it can be attracted by a magnet to bend one side or the other. If the magnet's taken away, the knife, because of its own springiness, will go back upright."

"Ay, that it will," agreed the mountaineer, glad to see at least one thing clearly.

"Well, I'm goin' to use the same idea. I've got a steel spring, here, with a piece of soft iron at the top, like a small hammer. Suppose I fasten that spring end-on in the frame I'm makin', just like the pen-knife was stuck in the table, an' fix it so that the hammer of the spring is about ⅛th of an inch away from the iron core. It's a cinch that, if I do that, an' then turn on the current into the primary windin', which, like I told you, magnetizes the iron core, that core will attract the little hammer across the ⅛th inch of distance. If I turn off the current, doin' which annuls the magnetism, the hammer will spring back upright by its own springiness.

"I s'pose it will."

"It sure will! But that means that I'd have to work the key myself, each time, to start an' stop the current. It'd be a whole lot better if I could make the thing work itself. As it happens, I can. This is how! In that socket in the frame I fit this wooden post, through which, near the top, I've driven a steel screw. Now"—he suited the action to the word—"I run a wire from the manipulatin' key to this screw. When I close the key, the current from the positive end of the battery flows as far as the screw.

"Then I take the steel-spring hammer an' fasten it in the frame close to this post, so that the back of the hammer presses hard against the screw, an' the front of it is about ⅛th of an inch from the iron core of the induction coil. This hammer, or vibrator, as it is called, is now ready for action. If I close the key, the current from the positive pole goes as far as the hammer, passin' through the screw.

"This leaves only one more thing to be done in the circuit, an' that is to attach this long piece of wire from the right-hand end of the primary windin' to the base of the steel spring which has the hammer at the top, leavin' the key open, of course, while doin' the wirin'. Notice, Dad, that makes a complete circuit, except for the gap left by the key, which I can close just by movin' it.

"Now, see what happens!

"When I shut the key, closin' the circuit, the current comes shootin' along from the positive pole of the battery, goes through the wire to the key, along the key, through the wire to the screw fixed in the wooden post, down the steel spring (which is pressed against the screw), around the spiral-wound wire of the primary of the induction coil, an' through the return wire to the negative pole of the battery.

"That magnetizes the iron core of the induction coil. The iron core, bein' made into a powerful magnet, attracts the soft iron hammer of the vibrator. The hammer, bein' dragged forward by the force of the magnet, pulls the steel spring away from the screw against which it was pressin' an' through which the current is comin'. This makes a gap in the circuit. The instant there's a gap, the current stops. The instant the current stops, the iron core loses its magnetism, an' therefore its power to pull the hammer of the vibrator forward. The springiness of the steel vibrator snaps it back to its first position against the screw.

"But, Dad, as soon as the vibrator touches the screw it closes the circuit again. The current starts an' magnetizes the iron core which jerks the vibrator forward again, breakin' the current once more. Back flies the hammer, makes contact with the screw, an' starts the current again.

"That way, so fast you can hardly see it, the vibrator flies back an' forward, makin' an' breakin' the current automatically. If I wanted to make the spring a bit longer an' to put a bell close to it, then, as the magnet pulls the hammer forward the spring would first hit the bell an' then fly back, a dozen times a second, makin' a kind o' simple electric bell.

"I'm not goin' to bother about the bell, now, because, as I told you, Dad, what I'm really after is to make a model of the very apparatus with which wireless was first found out. So we'll finish puttin' together the rest of the induction coil.

" See, Dad," he went on, " here's another cylinder, wound with several thousand turns of a wire exactly ten times finer than the wire o' the primary windin', there bein' several layers o' these turns, with waxed paper between each layer. This is called the secondary windin'. This second cylinder is made so that it just slips snugly over the other. The two sets of wire can't touch, of course, because there's a thick layer of cardboard and waxed paper in between, an', of course, all the wires are insulated, the primary windin' havin' its wire cotton-covered an' the secondary windin' bein' silk-covered.

" Now, there's lots of queer things about an electric current, as I've found out, but I reckon this induction is the queerest of 'em all. At the very second of startin', Dad, an electric current not only goes chasin' along the wire of its circuit, but it makes a magnetic field around that wire, which bursts out sideways in all directions. These magnetic lines, when they cut across another wire, set up a current in that wire, although there's no actual connection between them. They call that an induced current.

"You'll have noticed that the primary windin' had thick wire and only a couple of dozen turns, and that the secondary windin' had very thin wire and several thousand turns. That's why the induced current has a tremendously increased pressure. A current of a few volts from a battery will get to twenty or thirty volts in the primary, and to hundreds or even thousands of volts in the secondary windin' of an induction coil."

"I don't see how," declared Burly Cecil, seeing that the boy stopped for some sort of comment, "but I'll take yo'r word fo' it."

"Now," went on Hugh, briskly, "we'll go on to the rest o' the Hertz oscillator. You see these two wires leadin' out from the secondary? They're the two ends o' the windin'. I'll connect them to these two metal plates with the rods an' spark balls, which I explained to you the other night when I was makin' 'em. Bein' condenser plates, they'll collect a lot of electricity before lettin' it go, thus makin' a heavy charge. So! That ought to be about right!"

He busied himself a few moments, testing every connection.

"Now, Dad, if you're ready!"

He pressed down the key, closing the circuit.

With a snap and a crackle, a torrent of heavy sparks broke across the spark gap of the oscillator, and some sparks showed also at the point where the vibrator touched the screw. (This last showed a faulty hook-up, for it revealed a loss of power, and Hertz, in his second model, shunted a small condenser across the vibrator to prevent these tiny sparks.)

A second time Hugh closed the circuit, and a second torrent of sparks, even more brilliant than before, broke across the spark gap between the condenser plates.

" I'll be tarred! " exclaimed Burly Cecil, stepping back in alarm.

Hugh fairly jumped with glee.

" There, Dad! " he cried. " Those are real wireless waves! "

The mountaineer stared at these violet flashes with manifest distrust.

" Ho d'yo' know they are? " he asked.

" That was just what Hertz had to find out," the boy replied. " It took him four years to do it! But I know how he did it, at last. See, Dad, I've got the contraption all ready! "

Hugh held up a hoop of wire, the circle being broken at one point by a pair of tiny brass balls, with a very small air-gap between.

"This is the Hertz resonator, or receiver," he explained. "These two balls are really the plates of a small condenser, like those plates in the oscillator, and the air-gap between is the dielectric. The hoop is just a thick connecting wire, which, because it's thick, hasn't much electrical resistance.

"I'll stick this ring up, right here, exactly parallel to the plates of the oscillator, and with its center exactly opposite the other spark gap.

"Watch, Dad!"

He pressed the key again, and, as before, the violet sparks poured across the spark gap of the oscillator.

"Keep your eye on the receiver, Dad!"

The mountaineer looked.

Across the tiny spark gap, in the hoop, small sparks were passing.

"I'll open and shut the key three times! You watch!"

In exact correspondence to Hugh's manipulation of the oscillator, three groups of sparks shot across the gap in the receiver at the other side of the stead.

"See, Dad! That's just a hoop of wire with two brass balls. There's no current attached to it, anywhere! But the sparks show there's a current passin' through, just the same. That's wireless! Here, by this oscillator, I'm sendin' waves, and over there, beside that resonator, you're receivin' the waves that I send.

"Take that ring farther away, Dad! Take it outside the stead! Take it to the house! So long as the resonator's parallel to the oscillator, it'll catch the waves just the same, an' the sparks will prove it! Walls don't make any difference! Distance doesn't make any difference! The waves will get there, just the same!"

Burly Cecil stared and stared. Dimly he realized that something—he could not grasp just what—was being sent through the atmosphere. And he could see for himself that there was no trickery about the resonator. A ring of wire, two brass balls, and that was all!

"It's powerful strange! An' yo' say that's wireless?"

"That's what it is, Dad!"

"Yo' mean it's with a thing like yon contraption an' this one that ships at sea can call fo' help an' get it?"

"With a transmitter built on this principle, but naturally much more complicated an' up-to-date. When the *Volturno* caught fire in the middle of the Atlantic, an' hadn't long to last, it was a spark coil like this one which sent out the distress signal an' which brought ten vessels to the rescue, savin' 521 lives. Don't you remember, Dad, I read you the story last winter?"

"An', right now, with that machine thar, yo' could send out a distress signal?"

"I could send it out, easy! Pickin' it up might be a bit harder. But sendin' —— Look here, Dad! Watch!"

With his manipulating key he made three quick, short contacts, one right after the other.

"What did you see at your end?"

"Three sparks."

"Short or long?"

"Leanin' to short, I'd say."

"Now—again!"

With the key, he made three long contacts.

"An' that time?"

"Three sparks ag'in, but longer."

He repeated his first signal.

"An' this time, Dad?"

"Three short sparks."

"Great! That's just how it ought to be! Three short sparks stand for 'S'; an' three long ones for 'O.' So three short, three long, and three short again, stand for S. O. S., the distress signal of the world."

"So!" Burly Cecil was visibly impressed. Characteristically, he turned the question to its local bearing.

"Wa'al," he said, "ef yo' see Cram Ireton comin' here wi' a gun, send out the S. O. S. fo' me, an' I'll come a-runnin'!"

"I can send it out all right," agreed Hugh confidently, "as you see, but it's the receivin' that'll give us trouble. We can try it, though!"

So, half in jest and half in earnest, the two spent the rest of the afternoon in the house, trying to adjust the Hertz resonator exactly parallel to the oscillator in the stead a hundred yards away, and exactly centred to it. They did not succeed that day, nor the next, nor for a week or more. Hugh was naturally persistent, however, and before going on to the making of any more improved models, he stuck at this adjustment until he achieved his end.

The wireless waves passed through the two walls, and crossed the half-made clearing between the two buildings. The signals came through faintly, but, at least, they came through.

This much accomplished, Hugh set himself to a study of the earliest devices suggested for the detection of the Hertzian waves and, in the evenings, he began to make for himself the various parts of an outfit precisely similar to that which was used by Marconi in his first experimental set.

Night after night the boy stayed up until the early morning hours. As his mother was a very light sleeper, and was easily disturbed by his coming into the house late after midnight, Hugh took up the habit of sleeping in the stead, as he had done during the time that Miss Ferguson had been the Cecils' guest.

Twice, late at night, after he had gone to bed, the boy thought he heard suspicious sounds in the brushwood and second growth timber which surrounded his log cabin, and he determined to make himself a microphone when he should have the time, such a microphone as was used in the trenches, toward the close of the World War, to detect the approaching footsteps of an enemy. But that was in the future. At present he was too busy following up the steps of the forerunners of Marconi: especially Onesti, Branly, Lodge, Popoff, and Righi.

Thoroughly tired, one night, after he had racked his brain for hours trying to puzzle out by himself the problems involved in the different systems of wave detection, Hugh threw himself on his mattress in the stead without taking the trouble to undress.

Vaguely, across his dreams, the boy became conscious of a slight noise, but this did not wake him up. Visits of ground-hogs, 'coons, 'possums, ground-squirrels, rats, and such-like were sufficiently common around the stead, standing, as it did, between the forest and the half-cultivated land of the clearing.

Suddenly, some semi-conscious sense of danger roused him. He came awake with a start, though still heavy and stupid with sleep.

For a few seconds he lay still, staring blankly.

A dull light glowed in the cabin; a sharp and characteristic smell—the smell of burning kerosene—made his nostrils smart.

Then, with a thrill of fear, full realization came.

The stead was on fire!

That dull red light came from smouldering wood!

The boy took one flying leap from his mattress, dashed to a little wooden shelf on the wall, seized all his books and treasures—including the priceless "Great-grandfather's Book," and spun round to the door, wrenching at the handle.

It was shut.

Blaming himself for his stupidity, Hugh shot back the bolts and turned the key, giving the door a push with his knee.

It did not move.

Impatiently, angrily, the boy gave the door a violent kick. Generally, it swung open easily.

But the heavy planks did not even shake under the shock. Hugh might just as well have kicked the log-house wall.

Exasperated, he threw himself at it, his whole weight on the point of the shoulder.

The shock sent him reeling backward, but the door did not budge.

For a single second, panic clutched at him. He was on the point of screaming.

Then his glance fell on his electrical instruments, and the sight of them steadied him. During four years he had gained the habitude of calm and reasoned thinking. His presence of mind returned.

A swift look around the stead showed him that the danger was great. The cabin was on fire in a dozen places, and, by some smoke which came seeping through from the windward side, nearest to the forest, he judged that it was on fire on the outside, also.

Escape was imperative. Again he shook the door violently. When it resisted, he scanned it closely to see why it should be fast.

The dull light of the smouldering wood gave but little illumination—yet enough.

There! Up there!

A long screw, evidently misdirected, showed between the door and the jamb.

A screw!

It had not been there the night before.

That was why the door would not budge. It had been screwed fast!

He was imprisoned in the burning cabin!

This must be vengeance, for a door could not screw itself. It must have been fastened from the outside before the fire had been started, or after it. The attack was deliberate, then!

Hugh hurried to the window, but without much hope of escape. Enemies who had taken the trouble to bar the door would not be likely to forget the window.

As he expected, the shutters would not move, and, through the cracks, the boy could see that planks had been screwed across them.

Escape was impossible. Door and window barred, walls made of logs a foot thick ——

There was but one resource—to try to put out the fire.

A step took him to the chute and his first glance gave hope, for the water was running. Almost at the same instant he saw that a clod of earth had been dropped through the window into the chute, damming it. The water had overflowed the chute and was spreading over the floor.

Water!

Was that water?

Wherever it spread, it carried fire with it! The tongues of the liquid were tipped with blue flame, and, wherever they touched inflammable material, this burned yellow, giving out a greasy smoke and an acrid smell.

That was not water! It was kerosene which was running down the chute!

And it was still running!

There must be some one, outside the stead, pouring it in!

The malignance of this deliberate plot to burn him alive sent a shiver, as of cold, down the boy's spine.

For a second time Hugh fought hard with a panic desire to yell. Then he realized that such shouts, confined in the heavy-built log cabin, could not be heard at the house, more than a hundred yards away. He bit his lips, determined that the Iretons —if it were they who were planning this horrible death—should not have the satisfaction of hearing his cries.

He returned to thoughts of escape.

It was easy to determine to put out the fire. But how was it to be done? He had no water, no sand!

The fire was gaining slowly. There were but few cracks in the rough flooring, admitting but little air, so that the kerosene-soaked planks burned and charred, instead of bursting into flame. The only inflammable articles in the place were his mattress and work-table. The boy put these as far as possible from the slowly spreading circle of kerosene, and, grimly, tried to beat out the fire with his coat. He had nothing else.

But his coat, flapping in the oil-soaked wood, became saturated, and, instead of putting the fire out, spread it.

Steadily the heat increased; steadily the air grew less and less breathable.

The boy's head throbbed to bursting, his lungs stabbed cruelly. Dully, he continued to fight against the fire, but, minute by minute, his energy sagged. And, ever, the red glare grew stronger.

In a dozen places the logs were charred; the floor was burned nearly all the way through at several points. When one of the planks should give way and cause a draught—the planks rested on four-inch scantlings put on flat stones level with the ground, so that he could not escape that way—all these glowing spots would break into flames. And then!

Despite the strain and the suffering, the boy's most acute distress was for his work. All his machines would be destroyed, all his models. Nothing would be left. He thought of them and their fate more than he did of himself.

The heat grew stifling. Hugh could see that he was losing in the struggle, but he kept on doggedly, though his movements were growing heavy and sluggish. The fumes of the burning kerosene, entering his lungs, were poisoning his blood.

Then, suddenly, there recurred to him his father's question, put ten days before:

"'Is it with a contraption like this one that ships at sea can call fo' help an' get it?'"

And he remembered his answer:

"'When the *Volturno* caught fire in mid-Atlantic an' hadn't long to last, it was a spark coil like this ——'"

When she caught fire!

But ——!

The boy leaped to the Hertz oscillator.

In the now threateningly vivid light, through his smoke-blurred eyes he peered at the connections and saw that they were in trim.

A pressure of the finger on the manipulating key ——

A sharp crackle and a streak of violet sparks ——

Outside came voices:

"He's started in to conjurin'! Let's go!"

The flow of kerosene stopped but Hugh did not notice. His eyes were on the key.

Steadily he tapped out:

"Dot-Dot-Dot, Dash—Dash—Dash, Dot-Dot-Dot," and a pause. Then again: "Dot-Dot-Dot, Dash—Dash—Dash, Dot-Dot-Dot," and the pause.

Out from the burning log house in the heart of a cove of the Alleghanies crackled the distress signal to which every man, everywhere, responds.

"Dot-Dot-Dot, Dash—Dash—Dash, Dot-Dot-Dot."

And, in the house, the boy's mother, who was a light sleeper, stirred.

Wondering what these sparks might mean in the middle of the night, for she knew how Hugh avoided disturbing her rest, she shook her husband awake.

"Burly ——" she began.

But the mountaineer, though a heavy sleeper, was an old-time hunter. Once aroused, he passed immediately from sleep to full alertness.

His quick eye caught the sparks at once:

"Dot–Dot–Dot, Dash—Dash—Dash, Dot–Dot–Dot."

He sent the bedclothes flying and leaped clear. His trousers went on with two or three motions, the belt whipped round his waist as swiftly as the coiling of a snake, he stamped his feet into his top-boots with two violent efforts, and he whirled for the door of the room, grabbing his rifle as he went.

Fearing an ambush, he ignored the front door, vaulted through the kitchen window and ran for the stead.

There was not a sign of any one around, but, from the thatched roof, whorls of smoke were curling.

He wrenched at the door. It was immovable.

"What's wrong, Hugh?" he called.

"Fire!" answered the boy, his voice cracked and husky from the rawness of his smoke-bitten throat. "The place is drenched with coal-oil, an' burnin' on the inside. The door's screwed fast, so's the window. Quick, Dad! I'm about all in!"

Burly Cecil was a man of action. He wheeled for the woodpile and came back in a moment with the axe, which, like all woodsmen's tools, was sharpened to a razor edge. Old lumberjack as he was, he saw the only weak place in that solid blockhouse—the short log under the window-frame.

The axe whirled high. Chips, three and four inches long, flew out under those powerful strokes like clay pigeons from a trap. The wood was dry and hard, but Burly's muscles were of iron, and, as an axeman, he was without a rival in the valley. It was not long before one end of the log was hewn through.

The instant that a hole was breached, admitting the air, the whole smouldering interior of the stead burst into flame.

"Oh, Dad! Quick!"

There was no need for urging. The axe flashed up and down with whirlwind speed, and the hough-ing strokes as the blade bit deep into the wood pulsed faster and faster.

The log cracked, parted and fell, bringing the whole window-frame with it.

Vaulting through the opening, Burly Cecil picked up Hugh, as if the lad had been but a small sack, and heaved him out-of-doors.

One glance showed the mountaineer that there was no chance to save the stead, but he knew how Hugh prized the contents. Though the flames were raging, now, fed by the kerosene, he stayed long enough to snatch up the books, the instruments, the boxes of material, everything that seemed to be of value, and hurled them one after the other out through the gap in the wall. They might be smashed, but at least the material would be there.

His eyebrows were singed and his clothing smouldering when he jumped out of that furnace into the open air.

In the light of the flames, he saw the water-chute disconnected from the mountain stream and caught the ruddy gleam of the fire reflected on two empty five-gallon kerosene cans.

"The Iretons?" he queried.

"I reckon!" answered Hugh feebly.

The mountaineer touched with his foot the wrecked oscillator, which he had pitched out of the window.

"They'd ha' got yo', sho', but for that!"

The boy looked at the tangle of cells and wires with a smile of possession.

"My wireless!" said he, proudly, and fainted.

CHAPTER VII

A HEAVY HAND

"So you're the fellow they call Sandy Ireton, are you?" said the stranger aggressively, as he came to a halt in front of the Ireton cabin. "Father of three ruffian boys that you haven't either sense enough or strength enough to keep in order!"

The mountaineer could hardly believe his ears. Thus to be bearded on his own threshold by a man he had never seen before! Ere he could collect himself sufficiently to retort, the newcomer went on:

"I'm surprised at you! One of the best farmers in the valley, so I'm told; an educated man, too, able to read and write. You'd ought to be grovellin' on the ground, like a worm, for very shame!"

Struck dumb by this fierce and unexpected rebuke Ireton stared at his interlocutor.

"What durn business is it o' yo'rs?" he snapped back.

"I've made it my business! An' where I put my foot down, I stamp, an' stamp hard!"

He looked it.

Almost as big as Ireton himself, the stranger was lithe and supple. His voice boomed with the arrogance of accustomed authority. His eyes, partly closed, glinted like winter sunshine on steel. Power and self-confidence were written in every line of the face. The mouth betrayed a certain weakness, but Ireton was not subtle enough to recognize it.

"Thar's no call for yo' to come hyar, so far as I kin see," he returned, "an' the quicker yo' get out, the ——"

"There's reason enough! Have you seen the last copy of the *Radio Realm?*"

"I've seen all I want to o' that paper," sneered Ireton, "an'," he added with hostility, "o' the kind o' folk that read it."

"You'll read this number! It tells about the burnin' down of Hugh Cecil's cabin, an' the doin's of your three bright boys! Dr. Cameron, of Foljambeville, wrote the account, an' he's certainly got a pen that doesn't stutter."

Ireton took the magazine handed him and ran his eye over the first few lines.

"I'll talk to Doc Cameron when I see him!" he burst out, stung by the crisp denunciation of the opening sentences. "It's an outrage ——"

"You're right it's an outrage," interrupted the stranger. "A bunch of ill-bred louts can't burn down the experiment station of a promisin' young amateur without hearin' somethin' about it!"

Ireton was livid with rage, but he held himself in.

"How do yo' know my boys had anythin' to do with it?"

"I don't know, yet. But I'm goin' to find out, an' don't you forget it, Sandy Ireton! An' when I do find out, whoever was mixed up in that burnin' act is goin' to be good an' sorry."

"What are yo'? Deputy sheriff?"

"No! I've never played politics. An' I'm not overmuch fond of the law. I'd sooner handle things in my own fashion. But maybe you'd like to know what I'm doin' here. I can tell you that in short order.

"My name is Magnus Thorn, better known as 'Buck' Thorn, an' I was a school-teacher, before the war. Right now, I'm out of a teachin' job—it's a bit too tame for my blood, as a rule—an' I'm helpin' the American Radio Relay League, which is an organization for seein' that American radio amateurs get a square deal. Hugh Cecil, down on the creek here, hasn't been gettin' a square deal, an' I'm goin' to see that he does. I'll do it peacefully, by preference, but any one that tries any funny business is goin' to find himself in the hospital or in the cemetery pretty durn quick!"

"Yo' talk big—fo' a school-teacher!"

"I said I was a teacher, before the War. I've done a few things since.

"When the World War broke out, an' the gang in Washington was too pussyfoot to have the nerve to act promptly, I joined up with the Belgians, an' handled field radio work in the trenches. A German sniper got me, an', when I came to, I found myself headed for a prison camp. A fake radio message an' the use of a Luger automatic got me out of there, an' I made my way to the North Sea coast. There I helped in the famous Underground Railroad for freein' Allied prisoners of war under the very noses of the Germans. That was hot work!

"When the real American spirit got worked up, and the United States got into the scrap, I took a job on a British mine-layer, that bein' the most excitin' stunt I could find. When, at last, near the end o' the War, an army of our own doughboys got over there, I applied for special signal work on the front, where they was plenty doin', an' stayed there till the signin' of the armistice.

"Peace didn't suit me. I joined the Whites against the Bolsheviks an' handled wireless for

Denekine until a dirty little hound from Kiev sold us to the enemy. I got out of that mess, though it meant an ugly scrap, an', first thing I knew, I was fightin' against the Reds again, this time with Polish troops.

"I'm just tellin' you this, Sandy Ireton, to remind you that a school-teacher can be a hundred per cent. American, an' a hundred per cent. he-man! An', in the War, a wireless shark who wasn't scared for his skin could get all the excitement he was lookin' for!

"When I got back to America, I found they needed some fightin' blood in the amateur radio ranks, an' so I jumped into that. Right now, I'm pluggin' hard for the Relay League, handlin' the boneheads who are blockin' the air because of ignorance or disregard of the rights of others, an' trackin' down radio crooks who are usin' the air for crime. That's what I'm doin'!

"So, when I read in this paper of the dirty deal that the folks of Ants'-Hole Creek had played on a youngster, just because he was doing his best to learn wireless, I reckoned I'd come down here myself, an' find out what's what!"

This recital was not given boastfully; on the contrary, it was told coldly and incisively. Angry though Ireton was, he had sense enough to realize that the stranger was sincere and in deadly earnest. He could not help but respect a man who was so frankly fearless and determined. There was a shade less of hostility in his tone as he asked:

"What fo' do yo' come to me?"

"Burly Cecil told me to. He said your boys weren't worth the price of the rope needed for hangin' them, all three, but he admitted that you were square."

"What then?"

"I'm goin' to clean up this valley, Sandy Ireton! Either you're a decent man, an' want things run right, here, in which case you'll help; or else you're not, an' then I'll just have to hand you what you deserve."

"Yo're all-fired sure o' yo'rself!"

"I am!"

Ireton reflected. However violent had been his first resentment to Buck Thorn, the Puritan strain in him forced him to realize the truth as well as the bluntness of the stranger's words. The crusading spirit awakened an echo in him, also.

"Ef I should tell yo' that I had nothin' to do wi' the fire?"

Buck Thorn eyed him closely.

"If you tell me so, I'll believe you," he answered shortly.

"I don't hold wi' swearin', but I give my word ——"

"That's plenty."

The stranger paused a moment, and then went on:

"You didn't go to the raisin' bee that Burke an' the others organized so as to put up a new log cabin for the boy."

"No. I wouldn't ha' done it, anyway, fo' I don't believe in wireless, an' I wouldn't ha' been welcome, ef I had gone."

"You don't believe in wireless!" Buck Thorn's voice rang with scorn. "You talk like a mule with blinders on, Sandy Ireton! You don't believe in wireless! Why, man, you don't know what wireless is, an' you haven't any idea what it's done for the world!"

The mountaineer's answering shrug of indifference evidently nettled the stranger, for he took a step forward, and raised his voice indignantly:

"You don't believe in wireless! Learn something, before you talk like a fool in his folly!

"You'll admit, most likely, that savin' life at sea is worth while? In the last ten years, more than fifteen thousand men, women, an' children have been saved from drownin' as a result of wireless help.

"You'll admit that savin' people from bein' burned to death in forest fires is worth while? Twice, in the last five years, wireless has brought rescue to American lumber villages menaced by the flames, once in Michigan an' the second time in Oregon.

"You'll admit that to bring a doctor to a sick or an injured man is a good deed? I could quote you, not one but a hundred cases: at sea, on lighthouses, in lumber camps, down in the mines or out on the lonely prairies.

"You'll admit that to bring to safety an aeroplane lost in the clouds is help in time of need? In every country of the world, to-day, radio stations guide aviators an' serve the purpose in the air that light-houses do on the sea. The U. S. dirigible *Shenandoah* was brought back to her hangar in a howlin' gale by messages from wireless stations; to take another case, if it hadn't been that the radio outfit of the French dirigible, *Dixmude*, was injured, that terrible tragedy of the air would never have happened.

"You'll admit that to give water to a caravan dyin' of thirst is a charitable duty? Not once, but a dozen times, have scientific and military caravans on the Sahara been guided to wells by French radio stations, equipped with Direction Finders, hundreds of miles away.

"You'll admit that to send food and relief to explorers ice-bound in the frozen North is work worth doin'? Twice this has been done, once by America an' once by Norway. Whalin' fleets in the Arctic are kept in communication with each other an' with the mainland, an' can get an' give warnin's about the movements of the Polar ice.

"You'll admit that to give help an' comfort to the aged, to the blind, to the crippled, to the incurable an' to the insane is something which every honest man would do if he could? In tens, yes hundreds of thousands of homes an' institutions, to-day, wireless is the sunshine of the helpless.

"An' you don't believe in wireless!"

Ireton winced. This was touching him on a tender spot. All summer long he had been posing as a radio opponent, simply because of the manifest degradation of the science by dishonest manufacturers of apparatus, by lying advertisers, and by broadcasting stations which pander to the cheapest and most vulgar taste. He was honest enough with himself to admit that the widespread and beneficent

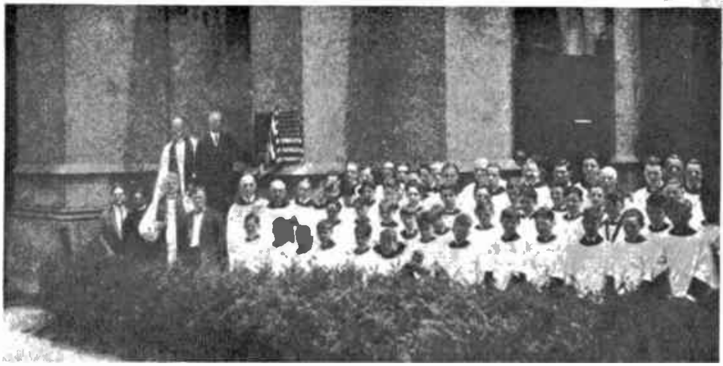
RADIO FOR INVALID VETERANS.

In convalescent homes or hospitals for chronic cases, such as Camp Kearny, shown above, head-phones which may be put on or not at the patients' pleasure, soothe many a restless hour.

Courtesy of Literary Digest.

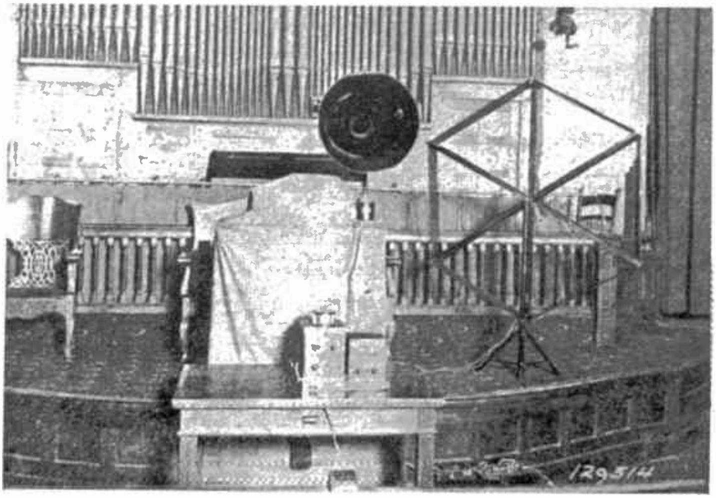
MAKING THE NEARLY DEAF HEAR.

Radio listening-in proves feasible to all people hard of hearing, and in some cases of almost total deafness it has had a marked beneficial effect.



Courtesy of Radio News.

Their Services Reach Thousands of Unseen Worshippers.
Calvary Church (Episcopal), Pittsburgh, on the occasion of the unveiling of a tablet subscribed by listeners-in from Quebec to Mexico.



Courtesy of QST

The Invisible Minister.
Herron Avenue (Presbyterian) Church, one of the many served by Calvary Church. Any church, meeting-house, or schoolhouse in isolated rural communities now can have sermons and choral music from the finest in the land.

utility of radio, as thus exposed, had not appealed to him. He had so blinded himself with his own opinion that he had ignored the best in blaming the worst. He saw quite well that a few such speeches by Buck Thorn—who evidently spoke with authority—would completely overturn the sentiment of the valley. He decided to try to find a middle ground.

"Jest what do yo' intend to do hyar, then?" he asked.

The stranger replied with another question.

"You're a school trustee, aren't you?"

"Ay, I'm one of 'em."

"Well, while I'm takin' the Cecil lad in hand, an' riggin' up a proper station—a radio relay point is badly needed on the line from Washington to Atlanta, an' there are none in these parts—I'm plannin' to teach school."

"Yo' are!" Ireton was manifestly surprised. "Yo' mean—hyar?"

"Right here. Down at the schoolhouse were Miss Ferguson was hazed, two years back. You see, I know something about affairs in the valley, already."

"Yo' know what we pay?" the mountaineer put in, eager to find some way of preventing the stay of so powerful an opponent in the valley.

"I know! Poor wages, inattention, an' ingratitude! That's what you pay!"

Ireton squirmed. This newcomer had an unpleasant habit of making the truth hit home.

"An' yo'd come an' teach school fo' that?"

"No. I've come for something else, as I told you. A wireless relay station is an absolute necessity in these mountains, an', since we've got the good luck of findin' a prize—a young fellow who's naturally interested in radio, we're goin' to take advantage of the opportunity an' establish a good station under his charge.

"Radio isn't learned in a few weeks, though, at least not real radio. We don't want dubs. Novices an' 'hams' who twiddle a few knobs an', because of that, think they know it all, are a danger to radio as well as a pest. They've got to learn, now, or else get off the air. It'll take all winter, at least, to train Cecil; maybe more. Durin' the winter, the youngsters of this valley ought to go to school. I propose to see that they go."

"But ——"

"I was talkin' to Wat Burke last night," continued the radio expert, ignoring Ireton's intended interruption. "He's secretary of the school trustee board an' he's goin' to call a meetin' for next Saturday. He'll propose my name for teacher. What'll you do?"

Ireton evaded the issue.

"Millennial Joe'll be against yo', fo' sho'!"

Buck Thorn frowned slightly.

"I know that. Millennial Joe's old, an' has queer ideas. He's lived a solitary life for a good many years. I don't want to be hard on him, anyway, at first. Let him come around gradually. We can't expect to do everything at once. It'll be enough, to start with, if the intelligent men take the lead. What are you goin' to do? Work for the best of the community or make trouble?"

The mountaineer looked at him steadily.

"Ef I vote fo' yo' as teacher," he said, with his accustomed candor, "folks'll believe I'm votin' to have a wireless station put in hyar!"

"They will," agreed Buck Thorn, scorning to dodge the issue, "an' they'll be right."

"The question is ——" began the school trustee reflectively.

"The question is," thundered Buck Thorn, "can you, as an honest man, deny education to the children of the valley?

"It's just a bit of vanity that's holdin' you back, Sandy Ireton. You don't want people to think that you've been made to change your mind on this wireless issue. Very good. I don't want to have to tread on a man's pride, unless he makes me.

"I'll make it clear to everybody that you're against me, if you like, an' that you're votin' for school, contrary to your best judgment, just for the sake of the children. That'll help your reputation, not hurt it. Now, what do you say? Let's have it straight, one way or the other!"

The mountaineer thought over this a minute.

"Yo've been plain an' honest wi' me, Buck Thorn," he answered at last, "an' I like that, though yo've a durn offensive way about yo'. But, fo' the sake o' the youngsters, I'll vote."

Thus it came about that a first-class wireless expert became the school-teacher at Ants'-Hole Creek.

Buck Thorn was right in saying that he had found a prize in Hugh Cecil. The boy's long, slow development, the learning of the fundamentals of electricity from "Great-grandfather's Book," the absolute necessity of doing everything for himself in the experimental line, the patient making of the earliest models from odds and ends picked up around the shack, the consequent growth of the spirit of mechanical adaptation and even of invention, the two years' correspondence course in mathematics under the guidance of Miss Ferguson, the learning of the Morse Code and of the principles of telegraphy from Jed Bladen, the books and the wise scientific advice of Dr. Cameron, and the endless copying of hook-up designs from the radio magazine during the long winter evenings, had thoroughly prepared the ground. The boy was not far advanced in actual radio knowledge, but he was ready to absorb good teaching; moreover, the hostility of his neighbors had stiffened his determination, and enhanced the independence of his character.

Buck Thorn knew the science of radio from one end to the other, theoretically and practically; moreover, in his adventurous career, he had also learned to know men. He had seen, at once, the possibilities which lay in Hugh, and the idea that perhaps he might have discovered a future genius —like Benjamin Franklin—in the poor mountain boy stimulated the ardor of this born fighter to whom radio was a passion.

In the newly built stead, Buck Thorn found Hugh finishing work on a full-size model of the first wireless set actually constructed by Marconi, that set, indeed, which had first given wireless telegraphy to the world.

That initial outfit, first installed on the Marconi estate, near Bologna, Italy, was not especially original. It was, rather, a combination of nearly all the experimental devices which had preceded it. Marconi's tentative wireless set did not contain a single device of his own invention, but, at the same time, the combination of these devices and the construction of them had been such as to make wireless telegraphy a possibility for the first time.

Marconi began with the system of Hertz, the main change being that he increased the size of the condenser plates and lengthened the rods (using wires, instead) which carried the spark balls. Following the idea of Popoff, he raised one of these plates on a mast—thus forming an aerial—and placed the other on the ground. This system placed the spark balls vertical.

The rest of the transmitting apparatus was exactly the same in principle as that of Hertz, save that Marconi used a much more powerful induction coil, which gave a six-inch spark. Instead of Hertz' small brass knobs, he made brass spheres, four inches in diameter, but separated them by only 1/25th of an inch. In this he was following the ideas of his teacher, Righi, the inventor of the three-spark exciter.

It was in the receiving set that Marconi showed his ability to take advantage of the advance in wireless ideas which had taken place in the eight years since Hertz' first discovery. The young experimenter entirely abandoned the circle of wire, known as the "resonator," realizing that this device was not suitable for reception at long distances, and —a still more serious defect—that it contained within itself no source of current and therefore no means of amplification. He adopted, instead, the idea of the telegraphic relay, by which a faint electric current, sent from a distance along the wires, is amplified by a local battery.

In order to work this relay more readily, Marconi erected a mast for his receiver, exactly like the mast of his transmitter, and, in the same manner, hung a condenser plate as an aerial and placed the other plate on the ground. (In his second set, the upper plate was changed to a square wire screen, and in the third set to a vertical wire; in both latter sets, the lower plate was eliminated, for Marconi had found that the ground itself served as a condenser plate.) For his detector—which the young fellow was keen enough to see was the real heart of the problem—he followed the improvements made by Guitard, Varley, Onesti, Branly, Lodge, Minchin, and Popoff.

In 1850, Guitard, a Frenchman, had noticed that when dusty air was electrified from an electric point, the dust particles tended to cohere into strings or flakes. This apparently unimportant observation became of the highest importance in wireless.

In 1866, Varley, an Englishman, developed this idea. He experimented with metallic dust, and devised a dust coherer which he used in his lightning protector for telegraphic apparatus. The dust was placed in a glass tube closed at each end by corks. Through each cork passed a wire, the ends of which wires were buried in the metallic dust, though they did not touch each other.

Under a low-frequency current, this loose dust proved to be a bad conductor; subjected to high-frequency currents, it cohered into strings of dust and became a good conductor. The coherer remained unaffected by the currents used for telegraphy, therefore, but the high frequencies of lightning instantly activated it, making the coherer so good a conductor that a dangerous flash could be grounded through it without injury to the telegraph instruments or risk to the operator.

In 1885, Onesti, an Italian, extended his researches in this direction, working on the theory of cohesion as a result of electrical influence. He found that iron filings possessed to a remarkable degree this property of change of conductivity. Under the impact of sparks (electromagnetic waves) discharged from an induction coil, the resistance of the iron filings dropped (or their conductivity increased) to a point where they became almost as conductive as copper wire. As, however, this was two years before Hertz' discoveries, Onesti's experiments did not bear directly on the radio problem.

The real discoverer of the method of detecting Hertzian waves was Branly, a Frenchman. He adopted Varley's tube and Onesti's principle of filings, and, after some experimentation, improved on both. He used a mixture of silver dust and iron filings, the metallic particles being packed loosely between two silver plugs. The wires ran into the silver, only. This coherer was attached to a battery, with a telegraph sounder in circuit.

When the filings were undisturbed, their resistance (in ohms) was so great as to prevent the battery current from passing. When high frequency Hertzian waves were received, however, these filings became instantly conductive, allowing the battery current to flow through and operate the sounder. This sounder, therefore, actually recorded Hertzian waves, and, in a laboratory sense, was a wireless receiver. Branly went farther, and placed an improved form of Morse printer in the circuit with the coherer, so that Hertzian wave effects could be translated into printed signals by means of his detector.

Sir Oliver Lodge, in England, treating the matter solely from the point of view of theoretical physics, demonstrated the efficiency of the Branly coherer as a sure method of proving the electromagnetic waves as forecast by Clerk Maxwell, and showed its extreme sensitivity to faint currents. Yet, though Lodge actually put up what was a wireless set, which received signals at a distance of 150 yards, it never occurred to him that this experimental device might be applied to long-distance telegraphy without wires.

Popoff, in Russia, came nearer still to solving the problem. He used Branly's coherer in conjunction with a Morse telegraphic printer, using steel filings instead of iron and silver. With this, attached to a lightning conductor, he was able to record lightning flashes so distant and so faint that the eye could not detect them. He also invented a "tapper" which automatically restored the filings in the coherer to their normal non-conductive state after the passage of each Hertzian wave. But Popoff, like

Lodge, failed to realize the enormous possibilities which lay under his hand.

Marconi, for his detector, took the Branly coherer just as it stood (the addition of nickel filings to the silver and the sealing of the glass tube were not used until the third set). Furthermore, he adopted the Popoff tapper, with slight change, and, for recording signals, used the Morse Inker.

In a few words, then, Marconi's first wireless outfit consisted of two low masts, each mast supporting a plate with a vertical wire leading downward to a spark ball, the wire from the opposite spark ball passing to the plate on the ground. In the transmitting set, the lower wire passed through the secondary of an induction coil to the ground, the primary having a vibrator and a key in circuit, the source of current being a battery of eight cells. The spark gap was directly on the aerial wire. In the receiving set, the lower wire had in circuit a Branly coherer for detector, a Morse Inker for recorder, and a small battery to operate the Inker when electromagnetic waves affected the coherer and allowed the current to pass.

Success came from the very start. The clear-headed genius of Marconi was evinced in his first set. He knew exactly what he wanted to do. The

Latin strain in him gave him logic and a common-sense ability to turn a theoretical discovery to practical use; the Irish strain in him gave him vision and an unfailing self-confidence.

As Righi himself said:

> "Marconi carried into the domain of practical reality that which had only floated indistinctly before the minds of others, or had served them for modest experiments."

The young Irish-Italian realized definitely that the principle which Clerk Maxwell had outlined thirty years before, and which Hertz had proved experimentally could be made to accomplish that great feat of telegraphing without wires which Trowbridge had accomplished in a minor degree by the principle of conduction, and which Preece had brought to commercial usefulness by the principle of induction. This new principle was that of the transmission and reception of electromagnetic radiation, or "radio."

Immediately after his initial experiments in Italy, Marconi went to England to confer with Sir Oliver Lodge. He put himself in touch with Preece, then Inspector-General of Telegraphs, and, from a room in the General Post-Office, London, he sent wireless messages to a roof over 100 yards away, with several walls intervening. Preece became enthusiastic and encouraged the young Italian, giving him freely of his advice and experience.

The next important improvement made by Marconi was in the receiving set. He removed the coherer from the direct circuit of the aerial wire and inserted therein the primary coil of a small oscillation transformer or "jigger," which acted by induction on a secondary winding, which, in turn, was connected with the coherer and recorder. Thus the impacts of the Hertzian waves on the aerial, setting up electric oscillations, were transferred inductively to the coherer circuit, allowing better results to be achieved.

With this apparatus, in 1896, Marconi passed a series of difficult tests before experts of the British Army and Navy. He encountered considerable difficulty in propagating a single and uninterrupted wave, for the reason that the electric waves generated by his induction coil were accompanied by a second series of oscillations of a different frequency from that of the original waves. This meant confusion as well as loss of power.

In 1897, using a coil that gave a 20-inch spark, and with vertical wires 150 feet in height, the young inventor succeeded in sending messages a distance of nine miles. In 1898, he established a wireless set on Queen Victoria's yacht, this being the first "ship-to-shore" station. A lighthouse wireless service also was organized.

At this point Marconi made the important advance of using the "jigger" in his transmitter, as well as in his receiver. This took the spark balls out of the direct aerial circuit. The transmitting aerial thus had the secondary winding of the jigger in circuit, while the spark gap was between the induction coil and the primary winding of the jigger. The effect of this was to enhance the purity of the emitted waves by preventing the second or irregular series of oscillations which, prior to that time, had passed into the aerial. These, now, were stopped, since the secondary winding of the jigger (and therefore the aerial) would only vibrate in unison with the oscillations set up in the primary.

In 1899, using jiggers (oscillation transformers took many forms, later) both on his transmitting and receiving sets, Marconi sent wireless messages across the English Channel, a distance of 28 miles. In the same year, the British Navy adopted the system. Before the end of the year, the 100-mile reception of wireless signals had been attained.

During these tests, the British Navy had constantly raised two very important objections to the wireless system of that time. The first was that, as electromagnetic waves radiated in every direction, and could be picked up by any one having a receiver, messages could not be private. The second objection was that, at great distances, these wave effects became so weak that reception was impossible with the methods then in use.

Lodge, in 1897, was the first to show the way to secure privacy. He laid down the theoretical principle of "tuning," in other words, of providing that a transmitter should only send a wave of a definite wave-length and that the receiver should only respond to that same wave-length. (If the ripples caused when a stone be thrown into water be taken for a simple illustration, the *wave-length* of a wave is the distance from crest to crest, the *amplitude* is half the distance between the height of the crest and the depth of the trough or hollow between the waves, the *velocity* is the speed of travel—usually measured in seconds, and the *frequency* is the number of waves propagated per second.)

Marconi, with characteristic quickness, grasped Lodge's theory and put it into practical form. At the same time he devised a means to increase the energy radiated by the transmitter. By adding these two improvements he set up this "syntonic wireless," with which he succeeded in sending tuned messages a distance of 155 miles.

This was the highest point that the Hertz spark transmission plan attained under Marconi's brilliant impulsion. It remains to this day a fundamental form of commercial ship wireless, though naval vessels use either the arc or the alternator transmission systems, spark systems having been abandoned in the U. S. Navy since 1915. Until as late as 1923 it was also the general system in use by American amateurs, though because of its interference with others (QRT) continuous wave systems have become necessary.

As the basic type of wireless, it should be understood. Consider the transmitter, first.

In Marconi's original set, the aerial wire passed through the secondary winding of an induction coil straight to the ground, and the spark balls were in direct circuit, the power impulse being given by a battery and the primary winding of the induction coil, with the usual interrupter or vibrator. In what came to be known as syntonic wireless, the aerial passed through the secondary coil of a jigger and thence to a tuning coil, which was a cylinder wound with a single wire. The ground wire was attached to a sliding contact, which moved across the turns of this tuning coil, thus lengthening or shortening the wire between the aerial and the ground and, consequently, increasing or decreasing the wave-length, just as the length of a pendulum determines the arc as well as the period of its swing. The primary of the jigger was excited by a spark gap in a circuit possessing a condenser of large capacity, consisting of ten Leyden Jars, the condenser being charged by an induction coil, receiving its initial impulse from a battery, as before.

The two circuits, one comprising the battery, induction coil, condenser, spark gap and primary coil of the jigger, and the other comprising the aerial and the secondary coil of the jigger, were tuned together by varying the number of included turns of the tuning coil (by sliding the contact point connected with the ground wire) until the oscillations of these two circuits vibrated in unison. The circuits were then said to be "in tune."

When this was the case, the electric oscillations set up in the condenser circuit by charging and by discharging through the spark gap created sympathetic oscillations in the aerial of similar nature and of maximum strength. Thus the energy radiated into the ether by the aerial was greatly increased, and consisted of a large number of slowly decreasing waves, instead of the abruptly stopped or quickly quenched wave-train of the original simple transmitter.

The same principle was used in the receiver.

In the receiving aerial wire was inserted the primary coil of a jigger, and, below, a tuning coil similar to that on the transmitter. The secondary winding of the jigger was connected to a small condenser, and thence to the coherer circuit and printer, as before. These two circuits were tuned together, and they were also tuned to the two circuits in the transmitter.

Thus the condenser in the transmitter stored up a considerable amount of energy and at each discharge imparted this energy to the transmitting aerial, setting up in it prolonged oscillations which died away slowly, so slowly, indeed, that one train of waves was still pulsing when the next one was started. As they were exactly tuned, the electrical impulses vibrated at intervals exactly equal to the free natural swing of the circuit. This gave a cumulative effect, just as a succession of taps, at regularly timed intervals, can set a great pendulum weight swinging, if those intervals occur at the natural period of swing of the pendulum. A big suspension bridge can be broken by a small boy jumping on it, provided that each jump occurs at the precise natural oscillation of the bridge.

In the same fashion, if the receiving aerial be exactly tuned to the transmitter, it will be affected by the cumulative effect of these waves. As radio frequency is at the lowest six thousand waves per second, these six thousand taps, if exactly timed, will produce a strong effect within a second of time. Thus a very feeble impulse, received at a long distance from a transmitter, will be built up in the receiver provided that the latter is exactly in tune with the transmitting station.

The coherer and inker worked faithfully in this early but famous outfit. Yet they were very slow, for one thing, and difficult to keep in order, for another. It was not long before Marconi abandoned them in favor of his magnetic detector. This was not a modification of other men's ideas but definitely an invention. It worked admirably and because of its sturdiness and handiness was used (mainly in portable sets for the Army) for more than ten years. Sets equipped with it are still in use.

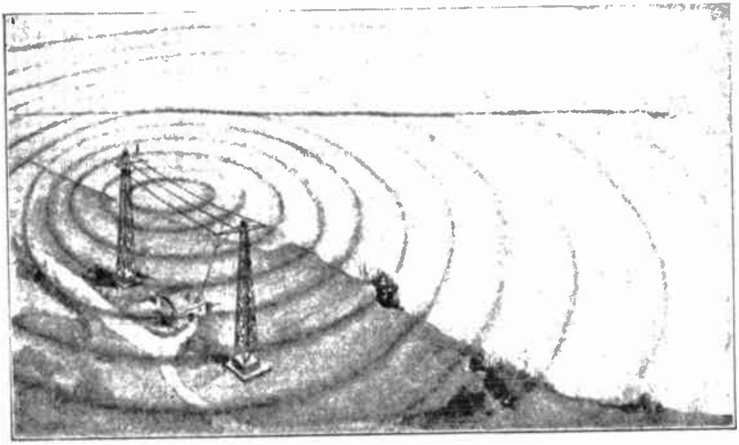
This invention consisted of an endless moving band of soft iron wire, rotating slowly on two pulleys moved by clockwork and passing through two small glass tubes on which silk-covered copper wire was wound. One of these coils was connected to a telephone receiver, and the other connected in the aerial circuit. Outside the glass tubes two horse-shoe-shaped steel permanent magnets were placed, in order to magnetize the slowly moving soft iron band. Thus, as long as the coils around the glass tubes were undisturbed, the iron band remained magnetized and an electric current constantly flowed through it.

The instant, however, that electric oscillations were received by the aerial, they activated the coil in circuit, and these high-frequency waves caused a reversal of the magnetism in the iron band. The effect of this sudden moving of the lines of magnetic force was to induce a current in the second coil, which was connected with the telephone ear-piece. For every spark at the transmitter, there would arrive a wave (or series of wave-trains) in the receiving aerial, the wave would start a current in the second coil, and give an audible "click" in the telephone. Since these clicks came at the rate of several hundred, or several thousand, per second, they would run together to form what the ear would hear as a continuous musical note. Thus, if the rapid succession of sparks in the transmitter were

Courtesy of Radio News.

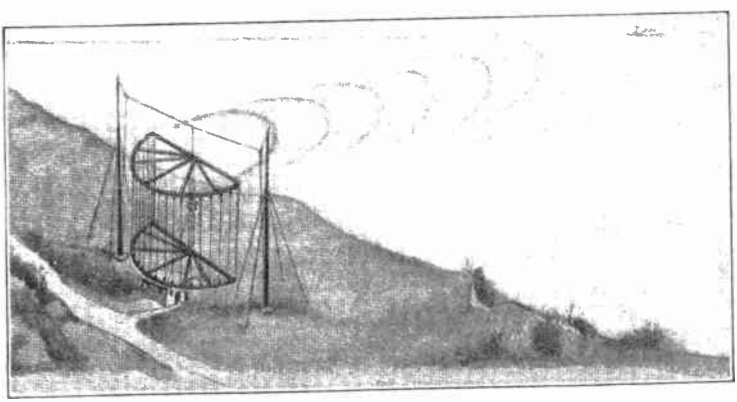
Small Chance for the Criminal.

Radio police car, equipped for sending and receiving. When accompanied by scouting police racing motor-cycles equipped with portable wireless sets, a fugitive is easily trapped.



The Old Way.

Hertzian waves transmitted in all directions equally, with loss of power when directive sending is required, as for instance, a station designed for "shore-to-ship" work.



Courtesy of Radio News.

The New Way.

Radio wave reflector aerial, providing greater efficiency for distance, giving a clearer note, and enabling direction-finding on board ship.

interrupted by a key, in accordance with the dot and dash signals of the Morse alphabet, a listener on the telephone heard this musical note broken up into short or long sounds.

It was with this magnetic detector that Marconi achieved his 155-mile record, from the Isle of Wight to Cornwall. The stride forward was enormous, since it permitted reception by telephone, and the combination of the telephone and the human ear forms an extremely sensitive instrument.

This much accomplished, Marconi set himself to what then seemed an impossible task—the sending of wireless messages across the Atlantic. For such a feat, the energy produced by batteries and induction coils was not sufficiently powerful, and at this point Marconi broke away from the initial form devised by Hertz. Fleming, who later attained great fame as the inventor of the thermionic valve, became Marconi's chief constructional engineer, and wireless entered upon a new stage, when large and costly installations became compulsory.

These steps in adaptation and invention, which Marconi had traversed with incredible swiftness of perception in a space of less than six years, were repeated by Hugh, under the direction of Buck Thorn, in six weeks. The first model was nearing completion when the wireless expert came to Ants'-Hole Creek, and, however difficult it had been for Marconi to solve the problems of development by strenuous experimentation, in an unknown field, once discovered the actual improvements were not difficult to make.

Hugh found out—as many boys have learned since—that nothing is easier to construct than the simple wireless apparatus with which Marconi worked such marvels.[1] The amazing thing is how the young inventor achieved such world-shaking results with such simple means.

By the time that school was ready to be opened, Hugh, under Buck Thorn's direction, had erected in the stead a transmitting set identical with that which Marconi had used for his 100-mile tests. He had also put up an aerial over the schoolhouse and had built into a strong cupboard there a receiving set of ancient pattern with a rough home-made Branly coherer and a Morse Inker. As the distance from the stead to the schoolhouse was only four miles, there was little difficulty in sending the signals.

[1] The Author holds firmly to the belief that many subjects—of which radio is one—are better learned by the use of the historical method. For a boy to be able to construct his own wireless set on modern lines, from bought parts, will never give the grasp of the subject to be attained by treading, anew, where all the pioneers have trod.—F. R-W.

The new school-teacher, accustomed elsewhere to the widespread and popular interest in wireless, was at first amazed, then annoyed and finally disgusted at the indifference of the children. Some of them considered it too difficult, others were afraid of it, and by far the larger proportion declared that their parents had forbidden them to have anything to do with the instruments.

This was not at all what Buck Thorn had expected. He had counted on being received as a public benefactor. He had promised himself to "clean up" the valley, as he had phrased it, in short order. Undoubtedly, if he had met with open resistance, he would have known what to do, and his aggressive fighting qualities would have had full play.

Here, however, he was out of his element. He had never before encountered the dull inertia of people who detested change and who were, at the same time, eaten up with pride. It was not that the cove folk were not willing to listen to reason; they were not willing to listen at all. The stranger could make no impression on them. Their flabby torpor was impervious to any attack.

Moreover, humiliating as it was for Buck Thorn to confess it to himself, his work as a school-teacher proved far below that of Miss Ferguson. Fewer children attended school, and those who did attend were less responsive. True, no one attempted to play tricks on him, but neither did he have a loyal following of his own.

Ireton had stuck by his word and had supported Buck Thorn in handling the school, but he had also maintained his personal opposition to wireless. The talks of Millennial Joe, too, continued to bear fruit.

Wat Burke, though a staunch ally of Hugh's, put the issue up to the wireless expert one day in the stead when he was being shown some of the later and more advanced work which the boy was doing.

"Things is goin' skew-eye, Buck Thorn," he said bluntly. "All this hyar electrical work may be A 1, but it's gettin' yo' nowhar, leastways, not as I see it. When yo' fust come, I reckoned yo' were goin' to be able to whip the creek folk into line an' to make this hyar radio popular. But the feelin' in the valley, now, is worse'n when yo' came."

The wireless expert nodded agreement. He was well aware of the fact, though he hated to admit it, even to himself. Finding that he did not answer, Burke continued:

"Ef yo' don't mind my sayin' so, yo've been goin' to work the wrong way. Cove folks ha' got their pride, maybe a bit too much of it, an' yo'r fust idea that they'd come in an' dance at yo'r whistle if yo' only whistled loud enough was clean contrary. I'm not attackin' yo', mind, an' I'm standin' by yo', strong, but it's never no use to fool ourselves.

"It a'n't yo'r fault, maybe. Folks is made different. Yo're not our kind, or we're not yo'rs—put it how yo' like. But yo've a heavy hand, Buck Thorn, an' yo're yankin' the bit on a skittish horse with a tender mouth, that's got to be handled light!

"Me, I've been playin' a knife-edge game between jealous neighbors an' revenue officers fo' thirty years. I know cove folks, an' I know signs o' trouble when I see 'em. Yo're goin' to get chucked off the saddle or kicked to a pulp, if somethin' favorable to yo' doesn't happen soon."

"I've told the folks here the truth about wireless an' I've explained its value, time an' again!" Buck Thorn declared. "They can't fall back on not knowin'! As for kickin' me to a pulp, I only wish they would start something! I'd show 'em what kickin' means!"

"Tellin' 'em doesn't do any good," retorted the moonshiner. "Half of 'em hyar don't believe yo', an' the other half don't care. How fo' is wireless on ships goin' to interest us folks in the mountains what's never seen a ship, nor yet the sea? What do we care about givin' the helpin' hand to aeroplanes? Thar a'n't ary a settler hyar what's goin' to travel in one! As fo' the North Pole an' the Sahara, yo' might as well be talkin' about the moon. An' yo' don't expect Ants'-Hole Creek to be worryin' its head about scientific progress!"

Buck Thorn did not blink, but he felt that every word hit home.

"What have you got in mind, then, Wat Burke?" he asked. "You haven't come here just to grouch; you're not that kind. You wouldn't open up this way, unless you've something more to say. I'll admit that my handlin' hasn't worked, so far. Have you anything to suggest?"

"Wa'al," replied the moonshiner, "ef yo' don't mind my sayin' jest what I think, I reckon yo'd oughter follow closer to the line that Hugh, hyar, begun on.

"When this electricity business first struck the creek, Hugh got a lot o' credit for helpin' my wife, an' he helped her considerable. Folks was favorable, then. Why? Because the lad was doin' somethin' fo' them. Ef my wife had been even from Sumac Fork, jest over the ridge, the folks hyar wouldn't ha' given a durn if she got better or worse.

They were interested because she's o' their own breed."

"It's not much to be proud of!"

"Maybe, but it's so! Now the boy, he a'n't gone far wrong, yet. What he put in the paper might ha' been written mo' careful, so as not to stamp on folks' toes, but we-all knew he was young, an' that bit o' hard feelin' would ha' soon died down. What got this whole shebang goin' wrong were the other articles in those magazines, specially the one about the singer. An' then, maybe, I let my own tongue get a bit rough, one day, when talkin' to Sandy Ireton.

"When the stead burned down, as yo' saw yo'rself, more'n two-thirds o' the men in the creek valley come to the raisin'-bee to put up a new cabin, an', in general, the men hyar don't do any mo' work'n they have to! Right about that time, Hugh was regarded plumb favorable, again.

"Then yo' come hyar, an' ever since yo' come, yo've rubbed folks the wrong way. Yo' told Ireton yo'd come to clean up the valley an' to show us what we oughter be. That's been repeated. But s'pose we don't want to be shown! An' s'pose we resent a stranger comin' in to try an' do it!

"Then yo' wireless ideas have been ploughed an' harrowed a-plenty. Ever since yo've been hyar, yo've been tellin' what wireless does fo' other people, an' yo've said yo're goin' to put up a relay station hyar. What fo'? Is it fo' us? No, it's jest to handle messages from the outside to the outside. 'Walkin' from one place to another over our necks,' was the way I heard one man talkin' of it the other day. It don't go!"

"It'll have to go," blazed out the reply. "You don't suppose I've come down here to establish a relay station—that's needed for the benefit of the United States, mind you!—an' have a bunch of 'poor whites' in the mountains spoil my plans!"

"They're Americans, jest as much as yo' are, Buck Thorn! An' they're on land where their families have been for more'n two hundred years. They've got their rights, an' they know it. They've got their ideas, too, an' though their notions may be queer an' out-o'-date to yo'r way o' thinkin', that's no crime!

"The heavy hand don't get nowhar in these hyar mountains, Buck Thorn, an' it's one o' yo'r friends who's tellin' yo'!

"We're isolated folks, hyar, an' we like to stay that way. What cove folks want to know is this: what's wireless goin' to do fo' the cove? Ef it can't do anything fo' us, right hyar, then"—Burke shrugged his shoulders, "why, thar'll be something happen. The stead'll be burned down again or the aerials wrecked or somethin' o' the kind, an', this time, thar won't be no raisin'-bee to help."

"You mean that all the work I've done here, teachin' school an' all the rest of it, even refusin' the salary the trustees offered, goes for nothin'?"

"Refusin' the pay didn't do yo' no good, it only made folks think yo' were rich. That made 'em hate yo' a bit mo', fo' we're not city folks who measure a man's wo'th by his dollars. An' as fo' the teachin', why, the folks hyar say that any woman would ha' done better, an' they wish, now, they had Miss Ferguson back. As fo' the general results o' yo'r stay hyar, it's tellin' against yo' an' the boy. What's mo', when yo' do get yo'r relay station built, it'll all be pulled down the first dark night, yo' can lay to that!"

Buck Thorn stretched out his muscular arms.

"Oh! If they'd only come out in the open!"

"Why should they?" queried the moonshiner. "Lookin' at it their way, things are goin' jest right. They belong hyar; yo'll have to go, some time. A waitin' game'll get 'em all they want.

"Yo're a fighter, Buck Thorn, they know that. I know it, too, an' I'm with yo' in this scrap. But it a'n't no use to fight when winnin' won't do yo' any good. Yo' can't force folks to like a thing.

"The way I see the deal, it's yo'rself yo've got to fight. Yo've got to change yo'r way o' thinkin', not theirs. Yo' can't lick everybody, yo've got to win 'em. Make yo' wireless serve the cove, then the folks'll come round. The backwoods o' the U. S. are the U. S. jest the same. Ef radio is so wonderful a thing as yo' say, thar's sho' something that it can do for us. Find that thing, an' do it! Thar's yo'r problem!"

Buck Thorn stared straight in front of him, his chin on his hands.

"Easy enough said," he declared. "But it's a tough job."

"It takes a man to do it. The point is—are yo' the man?"

Frowning, but no more daunted by the task than he would have been by a hostile gang, the wireless expert put his hand on Hugh's shoulder.

"We'll do it together, eh?"

"We ought to!" answered the lad promptly. "An', while I'm not sure, I reckon I know a way!"

CHAPTER VIII

WINNING OUT

If Buck Thorn and Hugh had worked hard before, they redoubled their efforts after Wat Burke's drastic talk. The boy's plan, which proved to be simple and direct, had received the enthusiastic approval of the moonshiner and the wireless expert. In order to carry it out, however, it was imperative that a wireless station of high efficiency should be ready by the spring and that the boy should thoroughly understand the handling of it.

Buck Thorn, once set on the right path, showed the stuff of which he was made. He was big enough in character to admit his faults, and resolute enough to force himself to adopt new tactics. He acknowledged his comparative failure in the teaching of school, went to Locustboro himself, and with rough eloquence persuaded Miss Ferguson to return. Since he had not touched the salary for the half-year, the trustees still had the money to offer. The girl agreed to come, on condition that she should stay at the Burke home, and with the understanding that she should not be annoyed by Cram Ireton. With Buck Thorn in the valley, there was little to fear on the latter score, for Cram lived in constant fear lest his part in the burning of the stead should become known.

This resignation from the school had an excellent effect. Those who liked Buck Thorn approved his frank admission that Miss Ferguson was a better teacher than he, those who disliked him flattered themselves that they had gained a victory, and one is always more lenient to a fallen foe. This pitying attitude irked Buck sorely, but he bit his tongue and kept from retort.

Burly Cecil urged that Ireton should be brought into the project, for Hugh's plan to make the relay station serve primarily for the benefit of the cove was calculated especially to meet Ireton's objections. Buck Thorn, who had not forgotten the stinging speeches of Wat Burke, suggested that the moonshiner himself should approach Ireton and try to restore the friendly relations which had been sorely strained. Burke made a wry face, but could not refuse to take a dose of his own medicine.

Ireton was far from being convinced. The utmost that he would do was to agree to withhold any active opposition, until such time as Hugh's plan should be in operation.

"Thar's three things I want to be shown," he said. "First, that yo' wireless actually works; second, that it'll bring some real benefit to the cove; an' third, that thar's some means o' controllin' it, so's it can't do mo' harm than good."

Ever a man of his word, Ireton did more than he promised. He let it be generally known that the wireless plans had been changed and that the new station was being constructed for the good of the cove. By prearrangement, every mention of wireless made by those who were interested in it was coupled with Ants'-Hole Creek. The settlers did not change their minds—that took time. But they stood pat. Burke, Ireton, Burly Cecil, Miss Ferguson, and Buck Thorn formed a solid block of support. In the spring, results would tell. Buck Thorn, freed from the irksome labor of school-teaching, promised that the station would be ready in March, and Hugh ate, drank, and slept wireless.

"You've learned what electricity is," said Buck Thorn, one evening, on their return from Foljambeville where they had gone to bring back some high-grade apparatus sent them by the Relay League, "you know something about magnetism, Jed Bladen has taught you wire telegraphy and given you some ideas about dynamos and electric machinery, you've constructed three or four sets of wireless—though all on the spark system, and you've done a lot of readin' about radio. You tell me, too, that Dr. Cameron has explained to you something about electrical measurements an' given you an idea of the electronic theory. That's a good start. You've followed in the steps of Hertz an' Marconi an' you've learned to handle Hertzian waves on a small scale. Now, do you know what they are?"

"Yes, I do," answered the boy, confidently. "They're electromagnetic waves sent out by the oscillations of an aerial, the oscillations bein' produced by an alternatin' electric current originatin' from a spark discharge or some other source of radiant energy. The work of wireless transmission consists of producin' these waves in the best form possible an' with maximum energy; the work of wireless reception consists of receivin' them, however faint and feeble they've become by distance, in amplifyin' them without distortion, and in understandin' the signals sent."

Buck Thorn nodded.

"There's a good deal more you might have said, but let it go, at that. What are these waves like?"

"Doc Cameron told me they were like a never-endin' series of soap-bubbles, one inside the other, each spreadin' out spherically indefinitely, never breakin' but gettin' thinner and thinner. He said, too, that magnetic lines of force, at right angles to these electric lines of force, spread out at the same time."

"Their speed?"

"The speed of light, 300,000,000 meters (186,300 miles) per second."

"What do these waves travel in?"

"The ether."

"An' what's that?"

"I can't explain it very well, Buck."

"Nor can any one else![1] Have a shot at it, though."

"Well, waves of water are carried by water, but they only go on the surface. Sound waves are carried by air. Neither the molecules of water nor of air change place, though. The wave motion is carried through them, or is transmitted by them. It's

[1] All theories of the ether are partial and unsatisfactory, but, since the U. S. Bureau of Standards, the U. S. Army and the U. S. Navy (the three greatest sources of radio information in America) uphold the theory of the ether, the author prefers to stand by it. The Einstein theory of relativity explains some difficulties, but adds others. The Steinmetz theory of space as a field of electrical force in which light waves and radio waves are but periodic alternations has grave astronomical objections.—F. R-W.

the same way with radio waves. They go through the ether or are transmitted by it.

"Just what ether is, I can't make out. It seems to be an invisible substance which holds everything in the world in it. Solids an' liquids aren't really solid or liquid, they're different states of holdin' matter suspended in the ether.

"Since—so Dr. Cameron told me—all solids are made up of atoms, an' all atoms are made up of ions which are as far apart from each other in the atom as the planets are far apart in a solar system, it must be ether which fills up the space in between. That way I can understand how electromagnetic or Hertzian waves—which are only vibrations in the ether—go through solids, because, being ether waves, the ions in each atom are too small an' too few to have any effect in stoppin' them."

"If light waves an' radio waves travel at the same speed, have they the same wave-length?"

"My word, no! A Hertzian wave may be as big as 23 miles from crest to crest, or as small as one inch—so said an article I read—but the biggest wave-length of light is 10,000 times as small as the smallest radio wave."

"Smaller than that, my boy. Ordinary yellow light (sodium) has a wave length of about one thirty-thousandth of an inch. Do you know what frequency is? "

" The number of waves in a second."

" Nearly correct, but not quite. It's the velocity of a wave multiplied by its wave length. What's the frequency of electromagnetic waves? "

Hugh came to a halt. He felt that he ought to know, but did not.

" That's a harder question to answer," admitted Buck Thorn, " because three such different effects as radio waves, radiated heat waves, an' light waves are all forms of electromagnetic radiation. Even the alternatin' electric currents used for commercial lightin' with a frequency of 60 per second produce electromagnetic waves of that frequency.

" Radio waves have frequencies of from 10,000 to 3,000,000 per second. Heat waves run from 5,000,000,000,000 to 200,000,000,000,000 per second. Light waves take the scale from 400,000,000,000,000 to 1,000,000,000,000,000 per second. The X-rays are three hundred times as speedy as the highest light waves, an' the radium emanation waves are seventy times as fast as the X-rays.

" Another thing which it's quite important for you to remember, Hugh, is, that, in this scale of electromagnetic waves, there are more gaps than there are waves that we know. Lower than the radio waves there must be waves whose properties are unknown to us. Between radio waves an' heat waves, there's a gap of unknown waves a million times bigger than our whole radio range. Between heat waves an' light waves, there's a gap of two million million in frequencies, an' the gaps between light an' X-ray, an' between X-ray an' radium are bigger still. Suppose across a foot-rule, you ruled two thick lines an' three thin ones, all five together not measurin' in thickness 1/32nd of an inch, you'd mark all that we know, so far, of electromagnetic waves. The rest is still to be found out. There's plenty of room for another Hertz, yet!

"Note this, too, Hugh! These waves may be converted from one group to the other. Radium emanations may be reduced to X-ray frequency. X-rays are used in such form that they give light. Light rays can easily be made to give heat, an', by the unique properties of selenium an' the electric current, can be converted into sound waves, so that, actually, the light of the stars can be heard. Sound waves are converted into electric waves in the telephone an' converted back again. High-frequency waves can be converted into low-frequency waves, an' this is done daily in wireless telephony when waves of radio frequency are reduced to audio frequency; in other words, when they are made slow enough to be heard.

"Now, do you know what amplitude is?"

"Yes, in a way. In a wave like water waves, which are only on the surface, it's the depth of the wave from crest to trough, but in radio waves it's the greatest displacement from the position of rest."

"Which, Hugh, if you'll think a minute, shows that your description of water waves is wrong. Amplitude is half the height from crest to trough. Be careful on that, or you'll be led astray!

"Now, how about wave form?"

The boy shook his head blankly.

"Did you suppose all waves had the same shape or form? Not a bit of it! How would the telephone or the phonograph work, then? It's the form of the waves which enables us to distinguish sounds, for example. Every electromagnetic wave has a different form, but this is more important in wireless telephony, an' you're not ready for that yet. At least you know the difference between continuous an' discontinuous wave trains?"

"There was an article on it, in a magazine, but I couldn't quite get the hang of it."

"You'll have to! Here, let me make it simple for you. Suppose a stone is dropped into a pool of water, not only one ripple, but a train of them will be produced. If a succession of stones be dropped exactly in unison with the first, or if a steadily vibrating body touches the surface of the water, continuous wave trains will be produced. If the stones drop irregularly, or if the vibrations are interrupted, discontinuous wave trains arise.

" The striking of a piano key gives a discontinuous wave train, the holding down of an organ note, a continuous one. The picking of a mandolin gives a discontinuous wave, the bowing of a violin gives continuous ones. Condenser or Leyden Jar discharges across spark gaps give discontinuous or 'damped' waves; high-frequency alternators, the Poulsen arc and the oscillating electron tube—all of which you've got to learn about, and in an almighty hurry!—give continuous or undamped waves.

" Undamped waves have a great advantage in radio. Thus, a dot in radio telegraphy lasts 1/20th of a second. With a spark discharge of 1,000 times a second there would be 50 trains in each dot, and with 40 waves in each train, the total number of waves in a dot would be 2,000. In undamped wave transmission, there are 10,000 waves in the dot, or five times as many. But the damped waves have only one wave of full amplitude, and the rest die away, while all the undamped waves have equal amplitude, giving, proportionately, about five times the energy. Thus the energy in a dot carried by the undamped or continuous wave is 25 times the energy in a dot carried by a damped or discontinuous wave, and it takes but little more power to transmit it. For another thing, an undamped wave is a pure wave, or a sharp one oscillating only to its own wave length; a damped wave is broad and blurred."

"An' can't continuous waves be got with a spark?"

"No. That was why, in the early days, Marconi worked on another system, first suggested by Wien and then developed by Fleming.

"This idea was to do just the opposite to making a continuous wave: the plan being to damp or quench the discontinuous wave train so quickly that only the first impulse counted. Wien did this by having the spark in the metal circuit take place between metal plates, instead of between round spark balls. If a series of ten metal plates were used about 1/50th of an inch apart, owing to the cooling of the metal surfaces, the spark across them all was instantly quenched and a pure impulse was sent into the aerial. Fleming improved this by rotating the metal plate spark gap in oil, so as to prevent arking the spark discharge.

"Marconi jumped away ahead on this by his invention of the high-speed disc discharger, in which a steel disc with studs projecting from each face rotates at high speed between two other discs rotating at right angles to it, these discs being in circuit with the condenser. Each time a stud passes, it grazes the two lateral discs, making a close spark gap, setting up an oscillation in the disc-condenser-jigger circuit. But the speed of the studded disc is so great that it opens the condenser circuit, instantly cuts short the condenser oscillations, limiting the wave in the coupled aerial to one single frequency.

"In the next stage of invention Marconi invented the smooth disc discharger. This is practically the same in principle as the former one save that it has no studs, and is adapted for the issuing of continuous waves. It was with these discharges that he first accomplished trans-Atlantic wireless telegraphy."

"But I read, somewhere, that he had to abandon batteries in order to cross the Atlantic."

"He did. He used an induction alternator, like the one Jed Bladen told you about, and which we're going to put up here. But he used the spark gap, just the same.

"The first trans-oceanic plant comprised a 25-horse-power oil engine, an' an alternator for producing a low-frequency alternating current at a pressure of 2,000 volts. This current was raised by transformers to 20,000 volts, and employed to charge the specially constructed condensers, made of a series of Leyden Jars immersed in a highly insulating oil. The condensers were discharged through Fleming's rotating discs, in the first experiments, through Marconi's stud discharger, afterwards.

"On December 11, 1901, a memorable day for wireless, Marconi received in Newfoundland the signal of the letter S (. . .) sent by Fleming from Poldhu (England). New stations were at once built, at Clifden (Ireland), Glace Bay (Nova Scotia) and Cape Cod (Mass.). Marconi's disc discharger was used at Clifden, and a new system of condensers, consisting of insulated metal sheets, suspended in air, took the place of the classic glass and tinfoil.

"On December 22, 1902, the first complete wireless telegram was sent across the Atlantic and, three months later, a regular service was begun. In 1907, wireless telegraphy had developed sufficiently to allow of a regular newspaper press service, and thence it developed until, to-day, wireless girdles the world, and every important power has radio communication with the most distant of its possessions: America with the Philippines, England with Australia, France with Indo-China, Italy with Somaliland, and Portugal with the East Indies.

"But, before leaving aside the spark systems altogether, Hugh, perhaps I ought to tell you that the quenched spark system, which Wien started, which Fleming improved and which Marconi used for the first trans-Atlantic work isn't by any means abandoned. Often the signals from quenched spark transmitters give a musical tone in a telephone receiver, due to the sparks following each other rapidly and with absolute regularity. That way, although they are discontinuous waves, under great speed they give the effect of being continuous.

"Assuming an operator's sending speed to be twenty words a minute (many are much faster than that!) the length of time occupied by a dot will be 1/20th of a second. With the increased disc discharger frequency of 1,000 per second, a dot would consist of fifteen sparks, enough to give a short piping note if heard in the telephone receiver, the pitch of which may be altered at will by increasing or decreasing the number of sparks per second. This distinction in pitch enables the receiving operator to concentrate on the particular note of the signal intended for him.

"Systems producing these musical sparks include the Wien, the Von Lepel, and the Telefunken. The latter has been developed into one of the most important German systems (using an alternator at some stations) which, prior to the War, maintained trans-Atlantic communication with America, and, since the War, has established several stations in Russia.

"So much for the spark! What other transmission systems do you know about?"

"I don't know anything about any other, Buck. I know there are some, because I've read about them. They seem to be mainly big-station stuff."

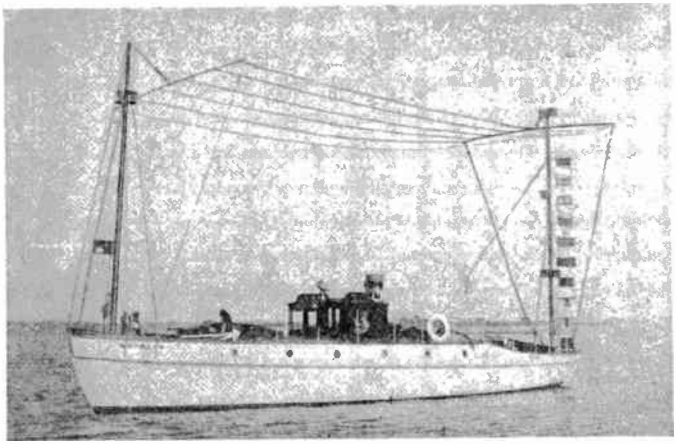
"Not a bit of it! A principle which works on a big station will work on a small one, though the contrary doesn't follow. It's distinctly up to you, as an American, to know about these systems.

"Every radio amateur should keep posted on what the U. S. Government is doing in radio, especially what the Army and Navy are doing, in order to be able to do his bit, any time the country needs him—in peace as much as in war. The amateur who hasn't found out the wireless developments of the Government, an' hasn't figured out some way to help on the good work is lyin' down on his job.

"So you'd better get wise to the three other transmission systems which are new to you. Not counting the revival of the induction principle by the Bureau of Mines, there are three principal ones: the Poulsen Arc, used largely by the U. S. Navy; the alternator system, either Alexanderson, Goldschmidt, or Army types, used in big commercial as well as in military work; and the Fleming or Thermionic Valve system, better known as the 'electron tube,' which is growing in importance, day by day. The 'tube' has already supplanted the spark in small stations, it is running the arc a close second, and, just the other day, big tubes were installed and made to take up the load of trans-Atlantic work, in place of the giant alternators. They worked so perfectly that the receiving stations, on the other side of the water, didn't even know that any change had been made.

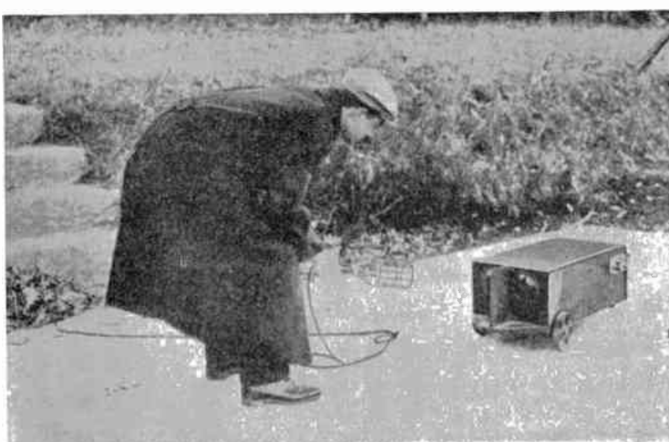
"Take the electric arc, first. What do you know about it?"

"Nothing," replied the boy, promptly. "I've never even seen one. I've seen pictures of city



An Electric Dog of the Sea.

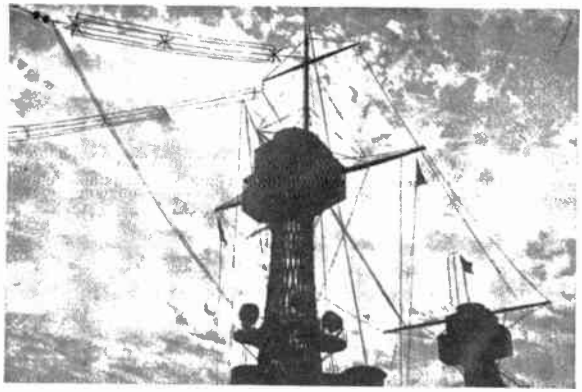
The yacht *Natalia* belonging to John Hays Hammond, Jr., the leading U. S. expert in radio control. Equipped with the stathmometer, this vessel will automatically steer for any marauding vessel showing a searchlight. The device is intended to be used with radio-controlled torpedoes.



Courtesy of Radio News.

The Electric Dog on Guard.

John Hays Hammond, Jr., the inventor of the stathmometer, taunting the "dog" with a light. It will follow a light in any direction or by reversing the current to the motor it will turn away from any light. It can be used as an extinction device for automatic lighthouses.



Antennae on the U. S. S. Colorado, the cage antenna being for the arc transmitter, the others for spark and radio-telephone.

Antennae on the electrically-driven battleship *Wyoming*. All the transmitters and receivers are within the area of the armor-plate.

WIRELESS FOR THE HOUNDS OF WAR.

streets lighted that way, but I've never been in a city. I've no idea how it works, because every magazine article I've read about its use in radio work took it for granted that every reader would know the principle. I didn't, and so I got lost."

"Then you'll have to learn it from the bottom, up, Hugh! Here's the principle of the thing:

"When an electric current passes continuously, or nearly continuously, through a small break in a circuit, the break being filled with air or other gas at atmospheric pressure, it creates a continuous discharge which is called an arc. It ionizes the air, if you know what that means."

"I do," said Hugh. "Dr. Cameron told me, when he was explainin' the electronic theory. It breaks up the atoms an' sets the ions flyin', that way makin' the air gap a conductor."

"Near enough. Well, the arc lamp, such as is used for street lightin', consists of a pair of hard carbon rods placed with their tips near each other. When an electric current is transmitted across the points, the carbon tips get incandescent an' emit a brilliant light. The space between the tips is filled with glowing carbon vapor, makin' the light still brighter."

"It's a kind of spark, then!" declared the boy.

" N-no, you can't call it a spark. Theoretically, maybe, it would be difficult to make a hard-and-fast line between the two, but in practice they're quite different. Arc discharges are constant an' nearly continuous, spark discharges are disruptive an' intermittent. Besides, the way of producin' an' handlin' the arc doesn't resemble spark apparatus at all.

" In 1900, Duddell, an Englishman, found out that if a circuit containing capacity an' inductance is shunted around a direct current arc, the arc will also give out a musical note. This gave him the idea that oscillations were being produced, and he soon verified this fact by putting a measuring instrument in the shunt circuit.

" Duddell's plan was simple enough. To the positive carbon of the arc he connected by a short wire the inner coating of a Leyden Jar; to the negative carbon he connected the outer coating of the jar by a wire containing a coil with a number of turns. The Leyden Jar, or condenser, gave him capacity; the coil of wire gave him inductance or inertia. Immediately after the current had been flowing a fraction of time, high-frequency oscillations were produced in the coil. Can you tell why? "

The boy shook his head blankly.

"To understand the how of this, Hugh, you must know that the electric arc, considered as a conductor of electricity, possesses very peculiar qualities. All conductors don't act the same way to the electric current, but, as a general rule, current is proportional to the electromotive force and to the conductivity of the conductor. This is called Ohm's Law.

"Curiously enough, the carbon vapor in an arc lamp doesn't follow Ohm's Law. It flies right in the face of it. An increase in the current through the arc is accompanied by a decrease in difference of potential between the carbons; a decrease in current causes an increase in potential.

"Now, let's see just what happened in Duddell's experiment, when a condenser and a coil of wire were shunted 'round the direct current arc. As soon as the current started to flow in the arc circuit, a little of the current flowing through the arc was diverted to charge the Leyden Jar condenser. This robbed the arc, true enough, but by the peculiar properties of incandescent carbon vapor, this loss of current increased the difference in potential between the carbons at the same time that it increased the difference in potential between the coatings of the Leyden Jar.

"This went on until the Jar could hold no more.

Then, since it wasn't able any longer to divert current from the arc, the current went back to its normal strength through the carbons. The increased current decreased the carbon potential, thus temptin' the fully charged condenser to discharge itself back across the arc. As soon as it was discharged, the opposin' currents neutralized each other, an' the cycle began all over again.

"By this system, as you can see, Hugh, the Leyden Jar is charged and discharged alternately, forming an alternatin' current in the shunt circuit from the direct current in the arc. The electrons—or the electric current—rush to and fro along the coil of wire. The frequency, obviously, depends on the natural period of oscillation fundamental to the condenser an' the coil of wire in series with it. If this frequency does not exceed 30,000 per second, the waves are audible. That's why it's sometimes called the 'musical' or the 'singing' arc. The principle was made clear, but the oscillations secured by Duddell were far too feeble for radio purposes.

"In 1903, Poulsen, of Denmark, took up the question from the point of view of its possible value for wireless. This was just at the time that Marconi had succeeded in trans-Atlantic transmission, but was handicapped by certain weaknesses in the spark discharge. Poulsen believed that the greater continuity of the arc discharge would help solve the distance problem. He proved to be right.

"The Danish inventor promptly saw the two main causes of failure in the Duddell arc: one was that the air in the gap did not de-ionize quickly enough, the other was that too much heat was generated. In order to overcome the first, he decided to make the 'air gap' in a rarefied medium which would de-ionize rapidly; for the second, he planned that one of the electrodes should be water-cooled.

"Thus Poulsen found that by formin' the arc between a positive carbon an' a negative water-cooled copper electrode, by enclosing the arc in a vessel full of hydrogen, coal gas, or alcohol vapor, at the same time placing the arc transversely between the poles of a powerful electromagnet, it was possible to obtain oscillations in the condenser circuit of such high frequency as to be available for wireless telegraphy, namely, at the rate of one million per second.

"Poulsen then simply connected up the coil in this circuit as the primary of a jigger, the secondary coil of which was in series with the aerial, an' tuned 'em together. The U. S. Navy uses another system of connection in its arc sets, takin' the copper anode directly to the aerial through a loadin' coil. Small arc transmitters are often provided with a 'chopper' to interrupt the radio-frequency oscillations, which are inaudible, to a vastly lower audio frequency, when they may be heard.

"Signallin' is done, preferably, through an absorption or 'tank' circuit, which allows only one wave-length to reach the aerial. Although this method has its defects, it is used on a good many high-power stations. One of the most famous of these is at Leafield, near Oxford, England, which is a controllin' station in British round-the-world wireless.

"So much for the arc. Do you think you've got hold of it?"

"Sure!" Hugh took up a pencil and sketched a rough diagram. "Something that way?"

Buck Thorn examined the plan, and made one or two small corrections.

"You've got the idea. Fine! Then we'll go on to alternators. Stop a bit, though! Didn't you tell me, one time, that Jed Bladen had given you an idea of dynamos an' electro-machinery, generally? Did he show you how an alternator works?"

"I've made one myself!" declared Hugh proudly. "It was one of the things which Father hadn't the time to save, when the stead was burned down that night."

"Good! Then you understand that all this complication of sparks and arcs wouldn't be necessary at all if we could build alternators to give a high enough frequency? All we'd have to do would be to connect one terminal of the alternator with the aerial and the other with the earth."

"But aren't we building 'em? Bladen said we were!"

"With tons of trouble and at enormous cost. The Goldschmidt rotating field alternator, with a complicated system of internally building up frequency by oppositely rotating magnetic fields, worked before the War, but the rotational speeds were so great that no kind of machinery would stand the strain and it crumpled up.

"The Alexanderson alternators, which are of the induction type ——"

"That's the kind I made, but small, of course!"

"Then I won't trouble to explain them to you. As you know, they're in use in America an' working admirably. But their cost is tremendous, an' they can't be expected to last long. The French La Tour alternator is of simpler pattern an' very ingenious, but not so reliable as the Alexanderson, though the new alternators at the great French station of Ste. Assise are perhaps as good as anything in the world.

"There's only one other kind of transmission system which you need to bother about, an' that's the thermionic valve, or tube. It was originally intended as a detector in a receiving set, and it remains, to-day, the best ever. As our knowledge of the thermionic valve advanced, though, astounding possibilities were found in it.

"From a simple Fleming two-valve detector came the marvellous three-electrode valve. This can be used to generate undamped waves and, by what is known as regenerative coupling, to respond to incredibly feeble impulses. Coupled in yet another way, as an amplifier, it can magnify incomin' waves almost indefinitely. It's by the use of thermionic valves or electron tubes as regenerators, as amplifiers and as detectors that round-the-world wireless has become possible. By a modification of the generator action and by constructing them on a large scale, thermionic valve or electron tube transmitters have been produced an' they bid fair to supplant all other forms of transmission.

"The electron tube is the most important thing in modern wireless, an', since I'm goin' to put some in for our receivin' station, here, you'll have to get the principle of the thing clearly in your head. But it's not easy to understand without seein' the tubes themselves. I've got some in the box which came to-night, an' I'll show you, to-morrow, just how they work. They're magic, if you like!"

Burly Cecil, who had listened to this explanation as he did to all Buck Thorn's talks—though without understanding more than one word in ten—interrupted at this point.

"This magic stuff is right interestin'," he said, "but I've been wantin' to ask yo', Buck Thorn, how Hugh's plan is goin'?"

"Ace-high!" declared the wireless expert. "I've written to every division chief and a good many of the district assistant chiefs of the American Radio Relay League, an' as there's not one who isn't a personal friend of mine, I've got enthusiastic replies from every one. They're willin' to go over the top, the minute we're ready."

"But jest how do yo' conjure to work all those folks?" queried the mountaineer. "Who's goin' to pay?"

"No one! Look here, Burly! There's over a hundred thousand amateur radio stations in the United States. There isn't a town of ten thousand that hasn't got a red-hot 'ham,' or several of them.

Plenty of places no bigger than Foljambeville have a dozen. Anyway, I miss my guess if there's a single inhabited place, in the whole United States, that some radio amateur can't get to with a flivver in an hour. I've lined up the whole country, an', right now, I can put my finger on any point on the map an' find a pal ready."

"An' yo' believe they'll be willin' to work fo' nothin'?"

"I know it! Some amateurs are in the wireless game just for the fun of it, merely trying to see how many stations they can hear in a night, or sendin' madly to find out how far they can be heard. There are a lot of 'em, though—I'm not talkin' about novices or broadcast listeners-in—who are real experimenters an' take the science seriously. They're the men who test out new ideas, the young fellows of whom an official of the Bureau of Standards said to me once:

"'We look to the American amateur as one of the great forces in radio. Any device which passes the discriminating test of usage in high-grade amateur stations has certainly proved its worth.'

"It was the amateurs of the United States who kept in touch with the Arctic explorer, MacMillan, when he got frozen in near the North Pole. Amateurs accomplished the trans-Atlantic jump, with low-power stations. Just the other day, they got across to Japan.

"When the storm swept over Minneapolis an' St. Paul, two winters ago, an' all the telegraph an' telephone lines went down in the blizzard, it was amateurs who got in wireless touch with Chicago an' secured help. Amateurs warned the villages all along the Mississippi the last time that old trouble-raisin' river was in flood. I could give you a list as long as my arm of important amateur achievements.

"There are a lot of complaints—mainly from broadcast listeners-in, who don't do a durn thing for the country—that the amateurs fill the air with messages of no importance. There's some reason for those complaints, an' that's why 'quiet hours' have been made compulsory, during the early evening, when broadcasting is at its height.

"I'll have to admit that amateurs have seriously injured their own cause by unmeasured huntin's for stations at a distance (DX), just for the sake of bein' able to say that they've received or transmitted a thousand miles or more with their home-made sets. But a lot of that is just blowin' off steam. Amateurs are restless because they haven't the chance to do enough useful work. That's why

Hugh's plan is eagerly seized on by any real 'ham' as soon as he hears of it.

"Look at it yourself, Burly Cecil. We're fourteen miles from Foljambeville, sixty from Asheville, an' the train connections are bad. There isn't an automobile in the whole creek valley, an', if there were, it couldn't cross the deep ford nor do more than crawl over the unmade road. In wet weather, it couldn't get through at all. There's only one buckboard in the place, an' that's Wat Burke's. The mail doesn't come any closer than Old Mill Branch, six miles away from the lowest house on the creek, an' Millennial Joe, who's supposed to have the job of walkin' down there an' back, collectin' an' deliverin' the letters, is old an' rheumatic. As you know, it's odds if he makes the trip more than once a week instead of every day.

"If any one in Ants'-Hole Creek wants anything urgent, it means either fourteen miles on foot or in a farm-wagon to Foljambeville, an' fourteen miles back—twelve hours of rough goin'. Or else it means writin' a letter an' wonderin' when Millennial Joe's rheumatism is goin' to let him take it to the post at Old Mill Branch. Suppose something really serious happened here! How would you get the news out? Suppose some one who lives here was badly needed on the outside! How long might it be before he found out about it?

"That's what we're out to change! We're goin' to put Foljambeville next door, an' Asheville just round the corner.

"That's where Hugh's plan comes in.

"Once we get this station fitted up, Burly, we'll be able to get a message to any part of the United States an' have a reply back here in less time than it takes a cove farmer to hunt his mules in the pasture an' to hitch 'em up. You watch us!"

"It's a durn shame yo' can't do it now," remarked the mountaineer reflectively.

"I could send, probably," Buck Thorn answered. "The new station at the top of the hill isn't ready, of course, but the improvements I made last fall on Hugh's old wireless outfit at the stead turned it into a fairly efficient transmitting station. But why is it a shame?"

"Wa'al, as it happens, ef it were all fixed like yo' say, yo'd have a chance to use it to-night."

"What?"

Buck Thorn leaped to his feet, his face alight with eagerness.

"A chance for us, Burly? Where? How?"

"I was a-talkin' to Simpson, down the creek, as

I come up to-night. It's not so much, but thar's a request fo' bids fo' some county road-work, an' Simpson has got two teams o' mules doin' nothin'. Ever since the hail got the most o' his crop, he's been wonderin' how he'd get through the winter that's comin'.

"Owin' to Millennial Joe's bein' old, like yo' were sayin', he a'n't been down at Old Mill Branch fo' three days, an' the letter askin' fo' bids didn't get to Simpson till this afternoon. The closin' time is to-morrow noon, at Asheville, an', as yo' know, thar's no way to get thar in time, even by walkin' all night. 'Tis a pity. It'd mean nigh two hundred dollars fo' Simpson, an' that's a lot o' money. Ef yo' could ——"

Buck Thorn burst in:

"Asheville! I know a bunch of stations in Asheville! There's 4KC, 4MI, 4GW, an' a lot more. An' that's only about sixty miles from here? If I couldn't wake up somebody in that burg with no more apparatus than a dry cell and a piece of barbed wire, I wouldn't call myself a radio man! An' there's that old Marconi model standin' idle, too!

"You chase down to Simpson, Burly Cecil, an' bring him up here on the run. Tell him that I'll get him that bid in, or I'll bust a hole in the ether doin' it. Sure, it's 'quiet hours' until ten-thirty, but by then I'll have things ready to sizz!

"You hit the stead in about three jumps, Hugh! Make sure there's juice in the batteries, an' go over the connections. No poor joints, mind! Use the solderin' iron if you're doubtful. Here's your chance to show what you've learned. Shades of Hertz! But that little spark will have to spit to-night!"

"But how are we goin' to know if any one gets our call?" queried the boy. "That coherer receiving-set in the schoolhouse won't ever pick up Asheville!"

"Never! But don't forget that we hauled back that box o' tricks from the railroad to-night, bully boy! An' I've got tubes in it, just like I told you!

"I'm an old U. S. Army radio hound, remember, an' I've been in places where we had to invent hook-ups from a tangle of wires all messed up with a German shell, with more high-explosive shells poppin' all 'round. This is only a joy-ride!"

He pulled out his watch.

"We've got an hour. I'd wire up a set to reach to China in that time! Get over to the stead, boy, an' make sure that everything's O. K. By the time Simpson gets here I'll have figured out some scheme to switch a receiving circuit into that old Marconi transmitting set. The aerial isn't much good, but I'll compensate for that, some way. Lively, now! Let me get at that box of junk! Where's the hammer an' cold-chisel?"

Buck Thorn was transformed. With a jumbled mass of apparatus, old and new, before him, he worked in the stead like a madman. Hugh, though he flattered himself that he had begun to know something about wireless, was absolutely lost in trying to follow the complexities of that improvised wiring plan. Buck Thorn never hesitated an instant. Extra batteries, old induction coils, binding-posts, twists of wire, variable couplers, transformers, tuners—half of them rewound or rehandled so as to serve some purpose for which they never had been designed—sprang into place, here, there and everywhere. They were assembled with what seemed to be an incoherent carelessness, but, despite the rough and temporary fashion of the doing, the wiring was rigidly exact. In the midst of this bewildering and apparently meaningless tangle of equipment stood one of the new electron tubes, which, on the throwing in of a switch, glowed brightly.

Hugh could not resist one question.

"What's the ——" he began.

"Tell you afterward!"

The spark began to splutter, but Buck Thorn spluttered more. It was not yet to his liking, and the air was blue with trench talk when Burly Cecil returned at last with Simpson.

"Write down just what he wants to say, Hugh," snapped the expert. "I'm going to CQ Asheville to a fare-you-well. When I get 'em on the air, I want to have the message pat! It's no time for long stories."

It took a little time to make Simpson explain just what he wanted to be said, all the more because he could not understand that his message must be brief. He wanted to tell the whole story of his loss by hail, merely as an introduction. At last Hugh got the wording down.

Meanwhile, the spark was crackling like a fireworks party, and the "urgent" call sped over the mountains.

From time to time, every half-minute or so, Buck Thorn switched over and listened.

"We haven't any call letter, not havin' any station listed," he explained to Hugh, "an' that's confusin'. Ah! There's some one!"

Dead silence in the stead.

"It's 4KC talking!"

The expert switched back to transmission and sent out a string of Morse. Then he settled back to listen.

"He says he's glad to hear we're on the air, at last. Idiot! I want action, not conversation!"

The next phrase in Morse must have been a swift one. On hearing the reply, Buck Thorn grinned.

"He says our spark is comin' in like coal slidin' down an iron chute. Now, where's that message?"

The paper was pushed in front of him, and the "brass-pounder" sent it off in smooth flowing Morse, ending the message with a brief statement as to why it was so urgent, and explaining that success would greatly help Hugh's plan, for which all near-by stations were waiting.

In reply:

"He says to wait a bit, an' he'll call us back."

Buck Thorn smiled at the mountain boy.

"I gave him HU (.... ..—) for a temporary call letter!"

A quarter of an hour later, the buzz of Morse could be heard in the telephone receiver clear and strong.

"That tube works like a charm!" muttered the expert and set in to listen.

"He says one of the Asheville 'hams' is the Mayor's secretary," said Buck, interpreting the dots and dashes of the code. "He says he just got hold of him on the air and gave him the message. The other fellow undertakes to get the bid into the right hands early to-morrow morning."

Burly Cecil gave a grunt of approval, but Buck Thorn held up his hand for silence.

"He says, too, that he knows the Public Works gang, and he'll do his best to put it through personally. He'll get the Mayor to back it. He says: 'Count it done'!"

It was thus, in getting work for a man who was in need, that wireless actually began its saving service in Ants'-Hole Creek.

CHAPTER IX

MAKING LIFE RICHER

The wireless message sent to Asheville on behalf of Simpson was the first thing which really startled Ants'-Hole Creek into a perception of the practical value of wireless. Not only was the bid accepted at once, but the County Road Superintendent wrote to Simpson, congratulating the creek folks on being so up-to-date.

Following on this success, several people wanted to send out radio messages, but, as none of them was urgent, Buck Thorn declined to receive them until the big relay station on the top of Sugarloaf Bald should be installed and put in working order.

Hugh's plan now began to develop, little by little. From most of the families in the cove he had secured the name and address of some relative living at a distance. The boy had written a letter to every one of these people, asking them not to go to bed before midnight on the evening of March 30, but to be ready to receive news from Ants'-Hole Creek.

For his part, Buck Thorn had sent word to some substantial radio " ham " and member of the Relay League, in every town on Hugh's list, bidding him be on the job on the fateful evening, to stand by and be ready to deliver personally to the address enclosed a wireless message which he would receive that night. A reply was to be asked for, and sent back over the air with as little delay as possible.

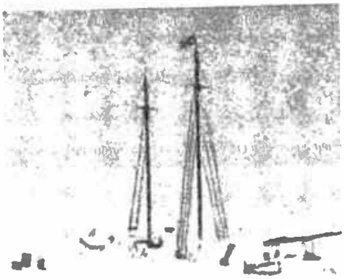
The various radio magazines of the country became greatly interested in the test, for it was felt that this effort to bring an isolated mountain community into touch with modern American life was a work worthy the doing, and a patriotic duty.

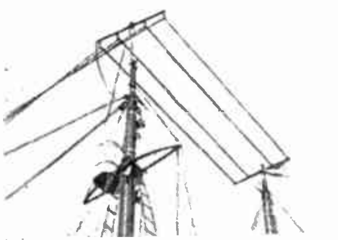
"This is real U. S. Radio for the people of the United States," one of the most important of the magazines declared in an editorial. "American amateurs have shown what they can do in times of war, they have shown what they can do on occasions of national or local calamity, here is their chance to show what they can do under the normal conditions of every-day life. In all the towns named in this list, let all radio stations—including BCL receiving stations whose receivers *do* radiate in spite of everything—clear the air on the evening of March 30."

On that famous night, nearly all the people in the cove toiled up the round-peaked hill which stood at the junction of Sumac Fork with Ants'-Hole Creek, and which summit, by repeated tests, Buck Thorn had found to be the best wireless site in the neighborhood. From dark until ten o'clock, Hugh and Buck Thorn did the honors of the place, showing the apparatus and explaining.

The station possessed a complete installation, powerful enough to transmit to any part of the United States, and sensitive enough to receive from any good American station, however distant. The transmission was of the continuous-wave variety, a 20-watter with four 5-watt tubes. The "British aircraft" (also known as IDH) wiring circuit was used, a form by no means easy to tune, even when using a wave-length close to the fundamental, but giving exceedingly strong and clear oscillations. A motor generator supplied the direct current, belt-driven from a small induction motor, receiving its power from a gasoline engine, well muffled and in a sound-proof pit outside.

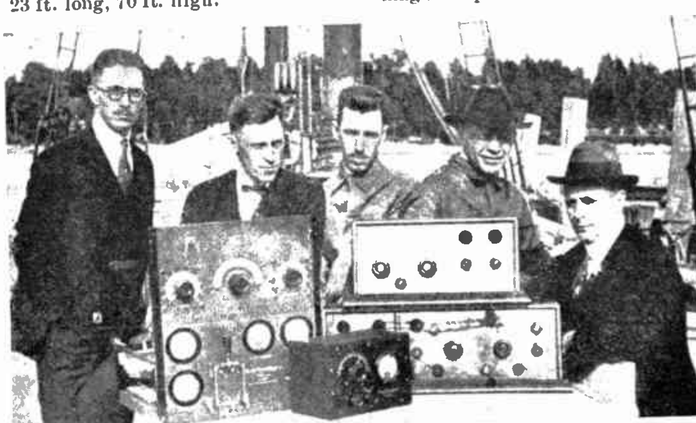
The receiving apparatus consisted of two stages of radio-frequency amplification, a tube detector, and two stages of audio frequency amplification, so wired that any one or all of the tubes could be used at will. Tuning was accomplished in a simple manner, by the use of honeycomb cells and variable con-





The Arctic exploration yacht Bowdoin ice-bound. A close-up view of her short but high aerial, 23 ft. long, 70 ft. high.

Dr. MacMillan, captain of the Bowdoin, in Arctic furs, ready for a sledge trip to test out Polar magnetic phenomena.



The wireless equipment unpacked. Dr. MacMillan is seated at the extreme right; D. H. Mix, wireless operator, is second from the left.

Courtesy of QST

A HIGH-GRADE AMERICAN AMATEUR RECORD; MAINTAINING COMMUNICATION WITH AN ICE-BOUND ARCTIC EXPEDITION.

CONTROLLING FIRE FROM AN AERIAL HEIGHT.
Forest-fire Air Patrol scout attached to the U. S. Forest Service, locating the fire and directing the fighters from overhead by wireless. Perilous work owing to the uprush of currents of heated air.

TESTING METHODS FOR RESCUE WORK IN MINE FIRES.
In the Hudson River tunnel, officials found no difficulty in sending and receiving signals underground. The U. S. Bureau of Mines now compels the use of radio in dangerous workings.

densers. Buck Thorn had planned to put in a ten-stage super-heterodyne, but some of the apparatus for which he had sent had not arrived on time.

To almost everybody present, the whole place reeked of mystery and instilled a sense of fear. The nine vacuum tubes, four in the transmitter and five in the receiver, blinked and glowed strangely, all the more strangely to people who had never seen any other form of artificial light than a candle or a kerosene lamp. The measuring instruments—volt-meters, ammeters and the rest of them—added to the weird effect of the unknown. To uninstructed eyes, such apparatus possessed occult power, comparable to the phials of an alchemist or the cabalistic spheres of a sorcerer. To his neighbors, Hugh seemed to move amid the glittering brass and coils of wire like a wizard. And, overhead, the fan of aerial wires pointed into Space.

Ireton alone, of the cove folk, had tried to learn something of electricity and of radio, his interest dating from the time of the success of Simpson's message. Buck Thorn's gibe that he was attacking something he did not understand had stung him sorely. Moreover, the mountaineer had begun to wonder whether the malicious character of his sons might not partly be due to the fact that they had nothing to occupy either their heads or their hands. Could it be possible that Cram might be induced to take an interest in wireless? Would this tend to keep him straight?

Because of such thoughts and hopes, Ireton was intensely interested in the new relay station, and, though outwardly still an opponent, secretly he was hoping that it might succeed. His slight reading, however, was of little value to him when confronted with this array of apparatus. He had secured a vague idea of what a spark discharge meant, but he knew nothing whatever as to the ways of an electron tube. This was clearly the occasion to ask.

As there was still an hour to elapse before the "quiet hours" demanded by broadcasting listeners-in were over, for the first message could not be sent out till then, Buck Thorn undertook to explain the principles of the tube as simply as he could, though warning his hearer that it was not easy to grasp in so short a space of time.

"An electron tube, or a vacuum tube," he began, "sometimes called a Fleming or a thermionic valve, looks a good deal like an electric-light bulb, as you can see for yourself, Mr. Ireton. If you'll examine one of them closer, though, you'll notice that it has more than the light-givin' filament inside it.

"There are three things inside: a tungsten wire or filament, which, when heated, gives light; a grid, which is a lattice-work of fine wire; an' a metal plate. The filament's got two wires comin' out of the tube, so that, when it's connected to a battery, a complete circuit is made, an' it lights up. The grid has only one connectin' wire out, an' the plate has only one. The circuits of the grid an' the plate, therefore, must be made across some sort of a gap.

"Probably you'll have read that all matter is made up of electrons, which are small charges of negative electricity. You may be aware that an electric current is simply a flow of electrons. You'll surely know that there are two kinds of electricity, positive an' negative, an' that unlike forms attract, while likes repel.

"There's one more important electrical principle you've got to grasp in order to understand the action of an electron tube. It's this: Metals, when heated, throw off some of their free electrons; the hotter they get, the more they throw.

"If there's any air or gas present in the space around a heated metal—such as this filament of tungsten—the projected electrons will strike the molecules of air or gas, an' will be stopped by friction. It's just to prevent that happenin', when the filament is heated, that all the air is pumped out of these tubes. That's why they're called vacuum tubes. It's essential for the workin' of a tube that nothin' stops the flow of these electrons.

"In order to make this clear, so's you can see it without confusion, I'll explain the operation of a vacuum tube in its three stages.

"First of all, Mr. Ireton, consider the filament as connected to a battery, just like I've got it here, but with the grid an' the plate not connected to any outside circuits at all.

"What happens?

"As soon as the metal filament is heated, it throws off negative electrons. These electrons, flyin' in all directions, strike the grid an' the plate. There they stick. The grid an' the plate become negative because they've got hold of an extra number of negative electrons. The empty space in the tube becomes negative, as well, because there are a lot of those electrons chasin' each other around.

"Like repels like, remember. As more an' more electrons are thrown off the hot filament, the triple repulsion of the negatively charged grid, plate, and space rises steadily until it gets so strong that the filament can't throw off any more electrons. A saturation point has been reached. The lamp remains constant, givin' out light an' no more.

"That's the first stage. Electric lighting works in something that way.

"Do you think you understand, Mr. Ireton? Here!" He sketched out a rough diagram. "That may help you a bit to see how it goes."

"I reckon I see a bit," came the reply, as the mountaineer thumbed the sketch, "but yo' talk so durn fast!"

"I'll go slower. It is a bit tricky to get hold of, all at once. I had hard work to pound it into Hugh's head, here!

"If you think you've got the general idea, I'll go on to the second stage.

"Consider the filament connected to a battery, just as before, but suppose, too, that both the grid an' the plate are connected to the positive pole of a second battery, the negative pole of which is connected to the filament. That puts a positive potential on the plate an' the grid. It makes a second circuit, closed except for the space gap between the filament and the plate.

"What happens, now?

"When the filament is heated, the negative electrons fly off as before. This time they get an extra hustle because the positive plate attracts them. The stream of electrons—which is a current of electricity, remember—closes the second or plate circuit. The battery then acts like a pump, pullin' the electrons from the filament to the plate, from the plate to the battery, an' out of the battery to the filament, which, bein' heated, throws them off again.

"As you can see for yourself, that makes a steady flow around the circuit, through the space gap in the tube, always in the same direction. It must be unidirectional since only negative electrons are thrown off by the filament and the plate is permanently connected to the positive pole of a battery. Note carefully that single-way flow, for it's more important than it sounds.

"In this phase, the vacuum tube can be used as a detector of wireless waves. It was so used by Fleming, who discovered it, an', even in the two-electrode stage (grid and plate being treated as one), it's a mighty good detector still. If the tube with the glowin' filament—call it the 'lamp,' to make it easier—be placed in the circuit of an alternatin' current, only half the alternating current will pass through the plate circuit, because of its one-way action. That half, though, will be direct current. If the alternatin' currents which come in to the lamp are wireless waves which an aerial has caught out of the air, the plate circuit will detect them in the form of one-way pulsations. The tube has become a detector, and if there's some kind of a recorder between the plate and the battery, the detected pulses can be recorded in any one of a dozen different ways.

"Do you get that, Mr. Ireton?"

"I'm a-tryin'!"

"The next stage is a bit more complicated:

"Suppose, now, that the filament is connected to a battery, as before; an' the plate to the positive pole of a second battery, as before; but that the grid is connected to a third battery, in a separate circuit. Let this battery be regarded as variable, an' the connections to the poles as reversible.

"What happens, this time?

"To begin with, consider the grid as connected to the positive pole of the third battery. This puts a positive potential on the grid. Right away, it increases the pullin' power actin' on the negative electrons, but since the positively charged grid has only a small surface area, most of the electrons will fly through it to the plate.

"Note carefully, Mr. Ireton, that a positive potential on the grid will increase the potential on the plate. Note, too, that any variation in the strength of the grid battery will increase or decrease the strength of the current flow to the plate.

"Next, let us consider the situation as if the connection of the grid to the poles of the battery were reversed, the grid bein' connected to the negative pole. Right away, bein' negative, it will repel the negative electrons. If the potential on the grid is weak (which depends on the strength of the battery) it will only diminish the flow of negative electrons pulled by the permanently positive plate; if the potential is strong, it will block the flow of the negative electrons an' stop the current in the plate circuit entirely. The grid is very near the filament, an' a small difference in potential will have a powerful effect on so sensitive a thing as an electron flow.

"This is the third stage. Now, let us see how it operates.

"In actual practice, the grid is not attached to a third battery, but it is connected to a third circuit, which is the receivin' aerial. That's how my first tube is wired here, if you can follow the hook-up. The plate is connected on the positive, as before, and a telephone receiver is in series between the plate and the battery. See, it goes this way!"

He indicated, with his finger, the actual wiring, and Ireton nodded as though he understood, though it was only in the vaguest fashion that he could follow at all. Hugh was listening with all his ears, for though Buck Thorn had drilled him thoroughly in this question, he was far from being absolutely sure of himself.

"You can see at once," the expert went on, "that any variation in the plate current means a variation in the telephone current. Remember, too, how I showed you that a slight difference in the grid potential causes a big difference in the electron flow or plate circuit. Any change in the grid, then, however slight, affects the telephone.

"Don't lose sight of the fact that the grid is inductively coupled to the aerial. When radio waves or high-frequency oscillations are received by the aerial, they are transferred to the grid, all the more clearly if a small condenser, shunted by a high resistance, be put in the grid lead.

"Now watch what happens!

"The radio waves are alternatin' currents. Each wave train, passin' from the aerial to the grid, reduces the grid negative potential, thereby increasin' the positive plate current. The periods of rest between the wave trains allow the grid electrons to leak back, restorin' equilibrium. This makes an unidirectional pulse in the plate circuit an' therefore in the telephone. Thus the feeblest waves, comin' from hundreds of miles away, can be detected in a telephone by the action of a grid not half-an-inch square."

"It's amazin'!" Ireton burst out.

"An' that's only the beginnin'! What's every bit as important is that the same tube, wired in very nearly the same way—but leavin' out the condenser—will not only detect these wireless waves, but make 'em bigger—amplify them, as we call it.

"By usin' the grid like a valve, or tap, not just to vary the current passin' through the plate circuit, but to close an' open it, the grid can operate a powerful battery in that circuit. Thus a feeble wave can be amplified about 100 times. From that point, one can chase ahead. By usin' an oscillation transformer, or jigger, this amplified wave can be taken to another amplifyin' tube. This will raise it to 10,000 times, an' so on.

"That's as far as I've gone, here, an' I won't need to use the second amplification except for very long distance. The less amplification the better, for amplifyin' not only magnifies the pure wave, but also all the 'strays' an' all the atmospheric disturbances that we call 'static.' With a moderate amplification, with a system of eliminatin' undesired wave lengths, with clean-cut detection, an' then with the magnification of the waves reduced to audible frequencies, almost anything can be obtained.

"There are a host of differently constructed devices for doin' these things, but all forms of amplification by means of the three-electrode valve owe their origin to De Forest, just as all tube detectors owe their origin to Fleming. Both of these men were started along this particular path of discovery by Edison, who first observed the result of electron bombardment in an electric light bulb, though he hadn't the faintest idea what it was.

"But there are other ways the electron tube may be used, too. One of the most important is called 'amplification by regeneration.' This was discovered in 1912 by Armstrong, an American, an' it is called the Armstrong circuit.

"He remarked that the incomin' wireless impulse often was slightly increased when the oscillation was intensified by a tube amplifier. This suggested that the tube possessed an inherent radiatin' power. Takin' advantage of this hint, Armstrong worked out a method of leadin' back a part of the energy from the plate circuit into the grid circuit, thus formin' what is called the 'feed-back' system. There are several types of these, an', though they were very satisfactory when the air was not crowded —there are over a million radio stations of one kind and another in the United States, now—the 'feed-backs' are gradually bein' cut out because of the re-radiation they are apt to cause."

"What is that?" queried Ireton, suddenly. "I read something about it, once, but couldn't understand."

"Re-radiation? It means that a wireless receiver, supposed to do nothin' but receivin', is radiatin' uncontrolled secondary oscillations. At least half the complaints from broadcast listeners-in that the 'air is jammed' come from their neighbors' receiving sets. To my mind, that bunch goes too far! Only the other day a BCL association asked the government to stop all ship to shore communication, all lighthouse signals, all commercial work, all army and navy directions, and to close the air to every useful thing while any broadcasting of jazz was goin' on! [1]

[1] This actually happened! But as between the egotism of the DX hunter, and the selfishness of the BCL, there is not much to choose. Both should be much more heavily restricted in the U. S. than they are. High-grade experimental stations should be afforded every facility. Broadcast programs should be rigidly held down. The air is *not* unlimited. It is as absurd to allow indiscriminate aerial traffic as it would be to permit push-carts

"This re-radiation, as I said, shows that a tube possessed radiating power. If plate circuit oscillations can be fed back to the grid an' thence to the aerial, it's only a matter of detail to amplify them an' control them for the purpose of radio transmission. This is bein' widely done, now. Those four tubes, there, are ready for that very thing. They can send out radio waves steadier and stronger than either a spark discharge or an arc.

"It's one of the fascinating things about radio," Buck Thorn went on, "that every new wrinkle leads to another. We haven't begun to find out, yet, what radio can do. Armstrong's discovery of regeneration, for example, led to the finding out of what is the most sensitive of all modern reception methods,—the heterodyne principle.

"To put it simply, this consists in generatin' an oscillation in a vacuum tube an' impressin' it on the oscillation which is coming in on the aerial. When the two sets of oscillations are of the same frequency, it is called a 'synchronous heterodyne,' an' the effect is to strengthen the wave, since both are beatin' together. When the two sets of oscillations are of different frequencies, but in a definite

and baby-carriages to roll at will on the right-of-way of the railroads.—F. R-W.

relation to each other, so that they beat together only at regular intervals, then it is the principle of the 'beat reception heterodyne.'

"Let me explain this a bit. Suppose, Mr. Ireton, you're walkin' along the road with a baby, a boy, a woman, an' a man a little shorter than yourself. The length of the baby's step is one foot, that of the boy is two feet, that of the woman is two feet six inches, that of the man smaller than yourself, is two feet nine inches, an' your own is three feet. When will each of them be in step with you? The answer is easy. The baby will be in step with you each time you put your foot down. The boy will be in step with you on your every second pace, the woman on every fifth, an' the small man on every eleventh.

"Suppose you do the same with radio frequencies. Tune two groups of oscillations close together, an' a large number of wave-beats will have to come before they're in step. In between, they'll neutralize. As this spaces the waves apart, it makes them easier to hear as well as amplifyin' them on the intervals when they beat together. It was Fessenden, another American, who devised this plan.

"I could go on with a good many modifications of these, Mr. Ireton, an' tell you of new developments in wireless, all the night long. But, by the time that you're sufficiently advanced to want to know what there is beyond heterodynes, you won't be in need of instruction from me.

"As you'll see for yourself, this station is able to do any work put on it, an' yet it's not too complicated. The manner of handlin' counts for as much as the equipment. The simplest is always the best, as long as it can do what's demanded. The test of this station will be, not the apparatus it's got, but its efficiency, to-night, in gettin' the messages over."

The hands of the clock pointed to ten minutes before the half-hour. Buck Thorn, once more and for the last time, went over his wiring and tested his controls. The voltmeter and ammeter, when thrown in circuit, registered the exact proportion of pressure and current. The generator was humming quietly. All was ready.

"Ten-thirty, Buck!" said Hugh.

The switch flashed over. The four transmitting tubes came instantly to glow. The key commenced to tap.

All the messages to be sent out—twenty in number—were piled in front of the sender, and to each one was pinned a slip bearing the call number of the station which had agreed to receive it.

Since, this time, there was no crackle of a spark, the faint hum of the generator and the clicking of the key were the only sounds to be heard in the crowded room.

Not more than a minute elapsed before the first station answered to its call.

"Athens, Georgia!" announced Buck Thorn. "That's your message, Wat Burke!"

He snapped to sending and rapped out the message.

"Norfolk, Virginia!" came the next announcement. "From Georgia to Virginia in three minutes is pretty good going, eh?"

Again out went the word from Ants'-Hole Creek.

In regular succession there followed Fairhope, Ala., Lexington, Ky., and Washington, D. C. These were the nearest stations on the list, and the receiving amateurs all reported the Sugarloaf Bald station transmission as clear and strong. The next reach was to New York, and then to Worcester, Mass., both of which got through without trouble, for both were stations of the finest kind.

Cincinnati, O., was slow and irritating. St. Louis, Mo., had trouble in receiving, taking up valuable time. The prairie States swallowed the Morse whole, Fargo, N. D., Omaha, Neb., and Ogden, Utah, receiving and answering as smoothly as if they were only a dozen miles away.

Trouble began in the Rocky Mountain region. Denver, Colo., reported a heavy snowstorm raging in the west. In order to make sure that his messages would not be held up, Buck Thorn relayed to Denver the messages for Santa Fé, N. M., Phoenix, Ariz., and Silver City, Nev. San Francisco, Cal., with a famous receiving station, answered at once, and, in spite of the storm, took a message for Tacoma, Wash., which had to be again relayed from Seattle.

The messages were no sooner launched than the replies began to roll in. Most of them were received on a single tube, and the clicking Morse could be heard clearly all over the room. Buck Thorn repeated each word as it came in, while Hugh transcribed them. Ireton, Burke, Simpson, Cecil received their replies in quick order.

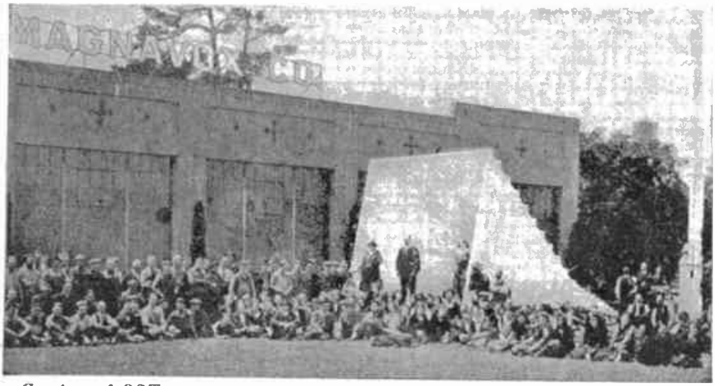
As the malicious imps of the air would have it, Silver City, Nev., where Millennial Joe's brother lived, was missing, and Denver could not cross the belt of the storm. Just at midnight, however, an amateur in Cripple Creek, who had been frantically summoned by Denver, got in touch with Silver City.

The enthusiasm had been growing steadily all evening long, each message received adding to the excitement. Many of the cove-dwellers had not heard from their relatives for years, since they were not able to read or write. The interest was intense, dramatic!

Some of the dispatches contained but greetings, but others bore good news. A few were tragic, and told of deaths unknown. The thrill of expectation grew and grew.

It was a few minutes before 1:30 A. M., when, at last, the reply from Silver City to Millennial Joe came in, completing the entire series. In less than three hours, twenty messages had been sent from Ants'-Hole Creek to twenty different States, including towns on the Atlantic and Pacific coasts, and replies had been received from every one.

When Buck Thorn had finished reading the Silver City message, and the announcement was made that not a single dispatch had been lost on the way, the usually impassive cove folks broke into wild applause. All opposition was vanished, all enmity forgotten. The radio station of Ants'-Hole Creek rocked with the cheering, and it was Sandy Ireton who led the cheers.



Courtesy of QST

The Largest Loud-Speaker Horn in the World.
This instrument was heard at a distance of 28 miles. The use of such devices is a menace to public peace and quietness.

Courtesy of Radio News.

Loud-Speaker Horns; Annoyance Size and Home Size.
Up-to-date loud-speakers now are built without horns. Laws are being framed to restrict the big noise-makers.

Five-tube set, bought, installed, and operated by the pupils of Junior High School 61, Bronx, N. Y.

Courtesy of Radio News.

The Harmonica Band of the school, playing before the microphone, the concert being heard by wireless as above.

DOING IT IN THEIR OWN SCHOOL.

CHAPTER X

RADIO AMERICA

"How many amateurs are scrapping their crystal sets, do you suppose, Buck?" queried Hugh, a few weeks after the famous telegraph relay test. The station on Sugarloaf Bald was working regularly now, moving wireless traffic in approved style, giving time signals to the valley, posting up weather reports, and acting as a sort of general news bureau.

"Scrappin' crystals, boy? Why, hundreds, I should say. There's a perfect mania for gettin' rid of 'em. It's a pity, too, for there's nothin' will give clearer results for short distances than a crystal, an' there's nothin' cheaper, anywhere! Why?"

"I was thinkin' ——" Hugh faltered.

"No harm to think!" prompted the expert.

"I've been thinkin' about the folks in the cove," the boy continued seriously. "After all, I'm one of 'em! We're a long way behind our times. We're clear out of the runnin'. An' the way I see it, Buck, it's because most of the folk can't read or write. That's what's left us at the tail!"

Buck Thorn instantly thought of a dozen other factors of degeneration, such as intermarriage, geographic isolation, bad cooking, moonshine whisky and the like, but he refrained from interruption.

"If only we could link the place up to the outside by wireless! If every one in the valley had a receivin' set, one which wouldn't need any fussin' over or elaborate tunin', don't you suppose this station would be strong enough to relay broadcastin' to 'em?"

His adviser saw the point at once.

"You mean—to put a crystal set into every shack? Is that the idea? Of course you could! Get 'em for nothin'? That's easy! The whole Relay League is interested in Ants'-Hole Creek. The news of our test got big space in the magazines, an' we're well known. Anyway, try it! Send out a bunch of calls on the air to-night, askin' for crystals, an' invite the 'hams' to spread the request. There must be tons of crystal sets lyin' on dusty shelves or corner junk-heaps. You'll have fifty outfits by the first post!"

"You think so?"

"I'm dead sure of it! Your receivin' end won't give you any trouble, though the puttin' up of good aerials and properly insulated leads-in at every cabin means a lot of work. It's the station itself which is the difficulty. It would have to be modified a good deal. We built it for wireless telegraphy, remember, not for telephony."

"I thought any good wireless station could be made to take either!"

"A first-class radio-telephone station hasn't any trouble switchin' to telegraphy, because the last is by far the most simple, but the scheme doesn't always work the other way. I suppose you know the principle of the telephone[1] and its difference from the telegraph?"

"Sure! Bladen explained it all to me one day. If I remember right, the main difference is that the telegraph works on the intermittence of a current, an' the telephone on the variations in a continuous current. That's why I thought we could use this station for telephony, because our tubes work on changes in continuous current."

"They do. But the kind of change we're makin' is in frequencies. We're tryin' to maintain a single buzzin' note, which is interrupted by the key when sendin' or receivin' Morse. That's a very different matter from recordin' the wave-forms of music and of speech.

[1] For the history and development of the telephone, see the Author's book in this same series: "The Boy With the U. S. Inventors" (Lothrop, Lee & Shepard Co.).

"Generally, when an outfit for both systems is wanted, the set is built for telephony, and buzzer modulation or some other device is switched in when only telegraphic reception is desired.

"Of course, as long as you've got a really good aerial, the power, and the tubes, it's only a matter of adding transformers, choke-coils, resistances, high-potential-batteries and a few things like that. But the amount of wiring needed to turn this station into a broadcastin' relay would be sure to be somethin' tremendous!

"If you don't mind my sayin' so, Hugh, I'm afraid it would tangle you up. You'd get such a maze of circuits necessarily confined in so small a space that if anything went wrong—an' you've got to make up your mind that something's always goin' wrong in radio—you wouldn't know where to begin to set it right. Even if you did know, you mightn't have room enough to tinker at the weak point without ripping half the circuits apart.

"No, if you really want to handle a plan of that kind, Hugh, you'll have to install a complete radiotelephone receiving and transmitting station. Same aerial, same power plant, of course, but separate tubes and circuits. If you put it on a sufficiently high-grade scale, you can get broadcast from anywhere, an' you can relay it to your cove folks on their crystal receivers."

"Well, let's!" cried the boy, eagerly.

Buck Thorn smiled.

"We've managed to get this station put up," he said, "because the amateurs of the country were very generous, because we were able to show the Relay League that it is an important relay point, an' because I reported Sugarloaf Bald an ideal site. But I wouldn't have the nerve to ask for a radio-telephone outfit, an', to tell the truth, I've already spent here a good deal more than I can afford."

"How do other broadcastin' stations work it, then? Somebody must put up the money!"

"That's a big problem, Hugh! The proper way to support broadcastin' is a thing which isn't settled. Some broadcastin' stations—which sends out really worth-while stuff—are maintained by the U. S. Government. A good many big stations are secretly supported by the manufacturers of receivin' sets, who figure that the profits on their goods are big enough to repay for the cost of installation an' operators. Several stations—such as those attached to mail-order houses—send out programs free because of the advertisin'. Commercial stations slip in publicity notices in the middle of the programs.

During campaigns, political parties pay to have the speeches of their candidates on the air.

"It's on a wrong basis, all of it, an' the worst feature is the mean trick of trying to persuade musicians, singers, orators, and actors, to give their time an' their work for nothin'. Broadcasting companies ought to pay for their talent, and pay well. Broadcast listeners-in ought to pay for their air programs, just as phonograph owners have to pay for records.

"I'll admit the money would be hard to collect, for how could one tell who tuned in, an' who didn't? An' what's more, any scheme of that kind would be resisted.

"The other day, when a questionnaire was sent to a large number of broadcast listeners-in, inviting them to subscribe voluntarily to the concerts they had heard, most of them replied that they had bought their sets on the understanding that there would be these programs free, and that, as it was, they had to listen to a lot of stuff they didn't want, in order to get some they did. What was more, a large proportion objected that they wouldn't pay for programs which they heard badly, or didn't hear at all."

"It wouldn't be any use tryin' to make the folks pay here," returned Hugh. "They haven't got the money."

Buck Thorn meditated a moment.

"After all," he said, "it's not up to you to change the system of the country. Take what you can get. If Newport millionaires want their air programs free, there's no reason why Ants'-Hole Creek shouldn't have them.

"Suppose you do this! Offer quarter of an hour's straight advertising talk every evening, five minutes apiece to each of three advertisers. For six evenings, that would be thirty advertisers. They'd pay five dollars a week, anyhow, maybe ten—not more, probably, because this section isn't thickly populated. That would give you a hundred and fifty dollars a week.

"Of course, it wouldn't always run like clockwork. There'd be a good deal of correspondence, an' a lot of trouble keeping the station in repair. You'd need an assistant, sure. But, if it worked out only to a half of this, that would be enough to pay interest on the capital investment for the building of the station, for repairs, for an assistant, and still leave a comfortable profit for yourself."

"An' that for only a quarter of an hour's talk a night?"

"Exactly. Then, after that fifteen minutes, you could tune in to high-grade broadcasting stations, and give the folks a concert or a speech free. You could read the newspaper in the afternoon and give them a little digest of it. Do that before the advertising, as a bait. Oh, it could be done all right, but it would mean a lot of work."

That evening, after the two had discussed the plan in detail, they went down to Sandy Ireton's shack. Hugh had not been there since the day when he had hidden in the woods watching the window of Miss Ferguson's room, and had shot Cram Ireton just as the young fellow was preparing to play an ugly trick on the teacher.

After brief greetings, Buck Thorn took the word.

"Mr. Ireton," he said, "Hugh's come for your advice. He's got another scheme in mind, which I think is a good one. He wants me to explain it. So I'll do it, in my own blunt way.

"Most of the people in this creek valley are ignorant. They don't know how to read or write. They don't see the newspapers an' they've got no idea of how the world is progressin'. Ignorance breeds conceit. Feuds start easily in these cove valleys, because men have an exaggerated idea of their own importance, an' they regard a triflin' slight or a scornful word as reason enough for startin' to shoot."

Ireton nodded agreement.

"Again, the people in this valley are poor. It's their own fault, absolutely. Every family has ten times as much land as it needs, an' the soil is fertile. But they raise poor crops, because no one teaches them how to farm, an' they don't half work their land because they've no ambition to live better than they do."

"That's true," the mountaineer agreed. "What then?"

"Now, Hugh's idea is this: Although the folks can't read, they can listen. Their ignorance can be cured by the ear, instead of by the printed page. Wireless can bring them the information what to do. The U. S. Department of Agriculture gives crop advice by radio to any farming community that asks for it.

"There's another thing which Hugh hadn't thought of, but which might be important. Grain and produce reports are issued by radio every day. If the folks here knew the price, they could sell at the highest mark. As it is, they take the long trip to Foljambeville when there are no more groceries in the house, takin' a few bags o' corn with 'em. In the town they're held up by the commission men, who give only half the price, knowin' the farmer has got to sell. It's a safe bet that if the cove farmer knew the right price an' when was the right time to sell, he'd get a lot more for his grain than he does.

"Then there's the social end of it. Why shouldn't Ants'-Hole Creek have the same chance to be an active community that any other place has, instead of being half-dead? You men, who are American citizens, ought to know what your country is doin'. The young fellows here, if they got interested in sports, would develop a whole lot better. The children could join corn clubs. The women, instead of hearing nothin' but the gossip of their neighbors, could learn by radio how to cook decently an' how to make preserves, for their instruction, an' could get music an' all sorts of things for their diversion."

This was a sore spot, and Ireton frowned:

"Music-hall songs, an' dancin'!"

"Certainly they can get that, if you give it to them," answered Buck Thorn. "They can't, if you don't. That's just what we've come about. Suppose we could manage to set up a broadcastin' relay station here, an' could give every one a small receivin' set, free, would you become the chairman of a committee to choose what should be sent out an' what shouldn't be?"

Will a duck swim? Could a Puritan refuse to become a censor?

Ireton made no pretence of hesitation.

"Yo' can count on me fo' that!" he said, emphatically. "Now, how do yo' plan to work it?"

The wireless expert outlined the project in full detail, explaining how he proposed that it should be supported. Ireton approved every step, with the exception of a demand that he should have the right to censor the advertising, also. This he laid especial emphasis upon.

"I don't want any fake medicines to turn the folks' stomachs," he said, "nor any gaudy clothes to turn their heads. I don't like this advertisin', noway, fo' the only reason of it is to try an' persuade folks to spend their money on things they can do without. But ef it's the only way to keep the scheme goin', all we can do is to hold the advertisers down. Ay, I'll help yo'!"

After the discussion of more details, the two turned to go, when the mountaineer put out his hand with a detaining gesture.

"Yo' a'n't got much use fo' my boys, have yo'?" he asked, turning to Hugh.

The boy hesitated a moment, and then said, frankly:

"I've kept away from them as much as I could, Mr. Ireton. There's no use huntin' trouble."

"Thar a'n't goin' to be any mo' trouble!"

He paused, and both his visitors realized that there was something that Ireton wanted to say which hung fire on his tongue. At last he got it out, in a burst:

"Yo' say yo've got to have a helper. Take my boy Will!"

Hugh made an involuntary gesture of refusal, but before he spoke the bitter retort which was on his lips, he caught Buck Thorn's look of warning, and changed his purposed phrasing.

"I'm afraid, Mr. Ireton ——" he began, haltingly.

"Oh! Talk out!"

"Well, it's this, then," the boy answered firmly. "I've never told it to anybody, but I know who set fire to that stead, with me inside, who barred the door an' put kerosene in the chute! Just as I started sendin' that S. O. S. over the old Hertz oscillator, I heard some one outside say:

"'He's started conjurin'! Let's go!'

"I recognized the voice, Mr. Ireton. It was Ollie's."

Will stepped forward quickly, and grasped the proffered hand.

"'Touch one, touch both'!" said he, using the stirring old phrase of allegiance, and the words rang true.

"Come to the stead to-morrow mornin'," said Hugh, surprised at himself for feeling satisfied. "We'll go up to the station on Sugarloaf in the evenin'."

"You've made a good stroke there," said Buck Thorn as the two came away. "I've seen something of Will Ireton. He's no fool. He ought to be useful to you, for he's got some of the qualities you lack. You'll never make an electrician of him, not in a thousand years, but he can handle business a sight better than you can. Whether you two can agree, of course, is another matter.

"Now, we'll have to get at this radio-telephone station installation in a hurry. I can't stay more than two weeks longer, as you know. In order to save time, I'll go to New York to-morrow, get the stuff, and bring it back with me Saturday."

"But the money?"

"I'll borrow the funds for you, on my personal note. Oh, don't worry! I'll fix up the papers so's they're strictly business. An', while I'm away, you

"I wasn't thar that night," came the reply. "But I helped carry the kerosene, a couple of nights afore."

"Why weren't yo' thar that night?"

Will looked his father straight in the eye.

"That's fo' Cram to tell!" said he.

"He shall tell!" declared the father. "Leastways, you weren't thar. Now, what about this offer o' Hugh Cecil's?"

"I'll go in!" answered Will promptly. "I don't blame Hugh if he distrusts me to start with, he's got a right to. As fo' his bein' the boss—o' course he'll be the boss; he knows more about wireless, now, 'n I'll ever know. But if he takes me on, after all that's gone afore, I'll say he has the right spirit an' I'll stand by him till the creek runs dry!"

"Yo' go on honor?" queried his father.

"On honor!"

Hugh hesitated, then, with an evident effort, held out his hand.

Will hung back.

"Is that jest fo' show, or do yo' mean it?" he asked abruptly.

"You're on honor," Hugh retorted. "If you've some mean trick up your sleeve, don't befoul your word by shakin' hands treacherously! But if you mean to go square—here!"

a little. But the memory of the burned stead persisted and this rankling injury made him answer a little bitterly.

"If Will comes to me," he said, "he comes for a job, not as a partner of any kind. He'll be a hired man an' I'll be boss. I'll tell him what to do. If he doesn't work, I'll fire him. If he does work, an' takes the trouble to learn, he'll have a good chance. I can't say more."

Ireton stiffened at this assumption of authority, unknown in the creek valley.

"Do yo' want me to call him?" he asked. "I won't answer fo' him if yo' put it that way. He'll have to say, himself."

"Sure, call him!" agreed Hugh. "Let's get it settled, one way or the other."

In a few minutes Will Ireton came in, and his father, without altering a word, told him what had been suggested. In spite of his obvious desire to be fair, his voice took on a hostile edge when quoting Hugh's words about the "hired man" and the "boss" and at the demand to have the right to dismiss at pleasure.

"Answer me straight, Will," concluded his father. "Did you take any hand in the burnin' o' the stead?"

"I'm not surprised," agreed the father.

"That's one reason why I keep away from your boys. I'd be afraid, if Will got into the station, that he'd wreck it the first time my back was turned. If he didn't, he'd give the chance to Ollie an' Cram."

"And if he went on his honor?"

Hugh moved uneasily. He could not very well tell Sandy Ireton that he considered the word of an Ireton to mean nothing.

"Understand," the mountaineer went on, "I'm not makin' this a condition. I'm willin' to help yo', like yo' say, whether yo' take my boy or not. I'm just askin' yo'."

"What do you think, Buck?" suggested Hugh, turning to his comrade.

"It's up to you to decide, lad. From my experience no one's as black as he's painted by others, nor as white as he thinks he is himself."

"Will's clever," admitted Hugh thoughtfully, but grudgingly. "Does he want to come?"

"Seein' yo' only just told me yo'r plans, he sho' knows nothin' about 'em. But I reckon he'd give the eyes out o' his head fo' a chance. He's been keepin' it dark from me, but I found some models he'd been makin', the other day."

Hugh thought of his own early days and relented go ahead and get me a bench and a panel made, also some extra wiring and switches, so's there won't be any delay when I get back. I'll make you out a diagram to scale.

"Now, just to start you on the right track, on the way back to the house, I'll give you a few ideas about radio-telephony. There's nothin' much to puzzle you, since you understand radio-telegraphy and wire telephony.

"Speech is composed of very complex vibrations, the wave of each sound havin' a most complicated wave-form. Telephony consists in reproducin' these wave-forms distinctly in a distant transmitter. Radio-telephony must achieve the same end without wires.

"In wireless telegraphy, when received by a 'phone ear-piece (head-phones) the pitch of the note is determined at the receivin' station, whether crystal, tube detector, autodyne, or heterodyne reception. For transmission of sounds of varyin' pitch, such as music or speech, the character of the waves is determined at the transmittin' station, an' depends on the nature of the current in the transmittin' aerial. By suitable handling, this can be readily done. In your case, since you plan only to relay to houses in the creek—an' perhaps Sumac Fork—you don't need a very powerful transmission set. A three-valve will be plenty.

"To get an idea of the whole thing, start with some one speakin' into a microphone—a telephone mouthpiece or transmitter. This is in circuit with a continuous current. As you know from the ordinary telephone, the waves of speech-sounds act on the diaphragm, which affects the conductivity of the carbon granules in the microphone, an' causes corresponding variations in the steady current. This current leads up to a step-up transformer, greatly increasing the voltage of the current, but maintaining its varying potential or wave-form characteristics. The high-voltage current acts upon the grid in Tube I. This Tube I is a low-frequency amplifier. It has its filament connected to a small battery, as usual, but the plate circuit which is connected to the positive of a high-potential battery passes through a low-frequency coil between plate and battery.

"Between Tube I and Tube II is a condenser. This condenser has two parts to play. For one thing it prevents the current and the positive potential of the high-potential battery of Tube I from reaching the grid of Tube II, and, for another thing, it changes the low-frequency direct current speech variations from the grid of Tube I into low-frequency alternating current variations, which, in that form, reach the grid of Tube II.

"Tube III plays the most important part in the work. This is an electron tube used as a generator, and generates continuous oscillations. Its plate is connected with the plate of Tube II but through a radio-frequency choke coil. Another high-potential battery feeds both the plate of Tube II and of Tube III. It furnishes a constant current because it has a low-frequency choke coil in series with it, and this choke coil keeps away from the battery any variation in current which might affect it from either of its branch circuits.

"Now, let's go on a bit farther, Hugh. The audio-frequency variation in the grid of Tube II produces an audio-frequency variation of current in the plate circuit. This variation cannot come from the second high-potential battery, as the low-frequency choke coil I spoke of prevents it; therefore it must come from Tube III. When the current in Tube II is increased, the current in Tube III is decreased, and vice-versa. Thus the amplitude of oscillation in Tube III is modulated by this increase and decrease of current."

"A minute, Buck; let me see if I get it. That arrangement of two high-potential batteries is to give strength for amplification, and the two high frequency choke coils and three low-frequency choke coils in different parts of the circuits are to confine the speech waves from being distorted during the process of amplification. Is that it?"

"Exactly. You can see that three of the four tubes in our transmittin' set could be re-wired to arrange a radio-phone system, but, aside from the complexity of wirin', there'd also be the danger of radiation actin' in a generative sense on the very delicate amplitude of the speech waves, distortin' them."

"I can see how that works. But won't it be a bit hard to work a receiving set here in the mountains sufficiently well to relay the broadcasting without blurrin'?"

"Oh, as to that!" declared Buck Thorn. "Don't expect too much! These stories of 'perfect' reception of broadcastin' from long distances are all bunk! Under certain conditions, with high-grade receivers, handled by some one who thoroughly understands them, when the air is not too full of 'strays' an' 'static,' tolerably good reception is possible from a moderately distant station, even good enough for amplification in a loud speaker. From a powerful broadcastin' station which is not more than 200 miles away, good results can be secured by high-grade detection without too much amplification. But broadcastin' relay is very tricky. You've all the faults of the transmittin' apparatus—nothing human is perfect—all the weaknesses of receivin' at the relay and transmittin' at the relay, the loss at the final receiver, and two sets of static.

"For a place like Ants'-Hole Creek, which is far out of the world, radio programs can be an inestimable boon. But the idea that broadcastin' can replace the real thing is jest plain crazy. Any man who tells you that a speech by radio-phone is the same thing as bein' in a convention hall, that a concert by radio-phone is as good as being right there where real musicians and real singers give of their best, that church services by a loud speaker have got the same inspiration an' devotion that you can get in church, is a double-backed, unregenerated liar! An' that's that! The main reason of its success at all is because most people are easily contented with poor stuff, an' are lazy to the marrow o' their bones.

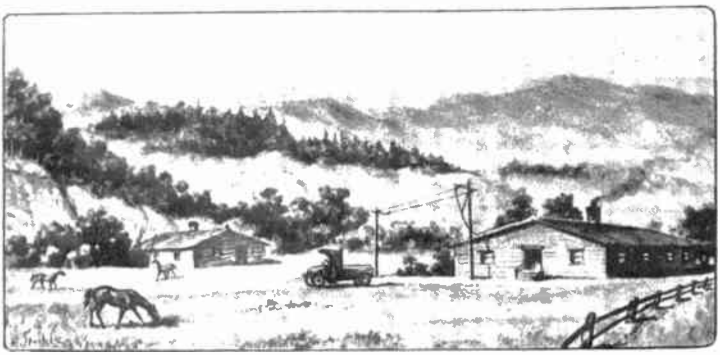
"There's no one keener than I am when it comes to U. S. Radio. What the Navy, the Army, the Bureau of Standards, the Weather Bureau, the Department of Agriculture, the Coast Guard Service, and a score of other Government services have done for the public by means of wireless ought to be blazoned in letters of gold! There's no praise high enough.

"But when it comes to second-rate commercial broadcasting companies—well? They have their use, perhaps, in isolated communities like this one. But, even here, I stick to the idea that the air shouldn't be used for twaddle, but kept free for things worth while, because a listener-in can't choose. He thinks he can, but he can't. It takes a high-power station an' a trained expert to tune sharp at long-distances. To say that any one can tune in, anywhere, is fraudulent. That's why programs should be kept to a high standard.

"If I thought that the station, here, would carry what is called 'popular taste' stuff—jazz, vaudeville jokes, sob-stuff stories, glad-hand talk, and propaganda—I wouldn't turn a finger to put the apparatus in. Ireton doesn't happen to be my style, personally, but I admire him for wanting to keep his own community a self-respectin' one!"

During the next two weeks, Ants'-Hole Creek was transformed. Even the most confirmed idler set to work. A large quantity of copper wire and several

In a Prosperous Farm Community.

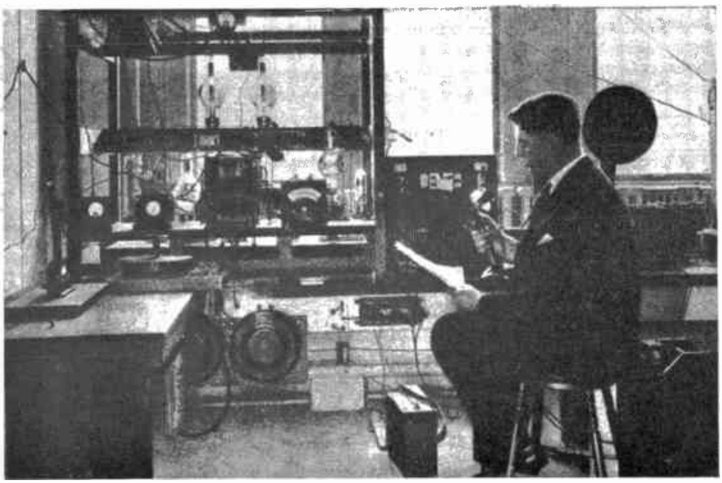


Courtesy of Radio News.

"We 'hill-billies' out in the 'sticks' look upon radio as a blessing direct from God. I am on a farm 100 miles northwest of St. Louis and 15 miles from the nearest railroad station. We have dirt road and six months out of the year a trip to the railroad station is a sixteen-hour job. We have been using a home-made crystal set for receiving the radio news and we feel that we could hardly get along any more without these (U. S. Agricultural) reports. We have not had service in our church since August, 1921 (two years), but we can listen-in to a good sermon or two on Sundays . . . "

From a letter to the Radio News Service, U. S. Bureau of Agricultural Economics.

The Radio Club Is the Latest Rival to the Pig Club and Corn Club.
Transmitting and receiving station of the State College of Agriculture, Washington, D. C., which gets the boys and girls out on the farms to extend the Market Report Service.



Eighty Thousand Farmers Listening.
The radiophone transmitting station of the U.S. Department of Agriculture, one of the most useful and efficient broadcasting stations in the world.

scores of insulators had been sent from Asheville. Every one in the creek valley started putting up an aerial, for Hugh's success in the telegraph test had caused all his neighbors to have confidence in him.

Masts were not lacking, for the creek was well wooded, and all the older settlers were axemen of the first rank. The aerials or antennæ were not very elaborate structures, for the reception was not intended to take anything further than the Sugar-loaf Bald station, not more than ten miles away from the furthest shack. But even the smallest aerial must be efficiently constructed, and Hugh realized that this gave him an excellent chance to try out Will Ireton. He spent all one day and two evenings, explaining to him the erection of aerials, the necessity of insulation, and the importance of making a good "ground" for the earthing wire.

"Get this, Will!" he insisted. "Electricity leaks much more easily than water, more easily, even, than air. I've shown you how to prevent it, by electrically tight joints an' absolute insulation. Go down to Simpson's place and boss the job of putting up the aerial. Boss it, mind! Tell 'em, good an' prompt, that I don't put a free receiving set into any house where the aerial hasn't got my O. K. and it won't get that unless it's done exactly accordin' to directions. It's a responsibility! Show that you're worth it!"

Rather to Hugh's surprise, Will handled the matter admirably. He escaped making enemies, and, although he was execrably unhandy with his fingers, he had so thoroughly understood what Hugh had taught him that he could show others just what was to be done, and why.

"You're doin' fine!" his chief declared. "I'll need your help, maybe, when I come to putting in the crystal sets. Of course, I can't expect you to understand the wiring of circuits, and all that sort of thing, just yet, but you'd better get the hang of it.

"All you need to know, to begin with, is that the wireless waves which carry speech to the big aerial on Sugarloaf Bald come in as alternating waves. To receive them by 'phone they have to be changed into direct current waves. The same way, what we sent out from Sugarloaf will be in alternating current, but what the folks will hear must be in direct current. That change is what's called rectifying, an' it's the job of the crystal.

"In 1906, General Dunwoody of the U. S. Army, who was an A 1 mineralogist, began a series of experiments on the conductivity of crystals. He found out a surprising thing. He discovered that crystals of carborundum—a substance used for grinding—allows the current to go through one way, but not the other, like the valve in a pump. Therefore, half of a back-and-forward (or alternating) current is stopped; the forward goes on, the back doesn't. The result is that the current passes in regular pulsations. Several other crystals have the same property, galena, or sulphide of lead, being one of the most common.

"If, then, the alternating current which is coming from the receiving aerial is passed through a flexible and springy piece of copper wire, called a cat-whisker, and if this cat-whisker presses hard against a piece of galena, the current will only go through in one direction. In other words, it will get the same result as if you have one of these elaborate tubes. Scientists haven't yet been able to figure out the cause for this lop-sided conductivity.

"To make sure that we get things just right, Will, we'll put in each set the simplest kind of a tuning coil, with a sliding contact along it. If that doesn't come close enough, we can put in variable condensers afterward. But we oughtn't to need them. For a radius of ten miles everything ought to be clear enough."

On the Saturday following, Buck Thorn returned.

He had spent nearly two thousand dollars on his set and had secured enough advertising contracts to enable Hugh to go ahead, meeting the interest, providing for depreciation, paying Will, making a good income for himself, and establishing a sinking fund for the gradual paying up of the capital. Will swallowed this avidly, and, as Buck Thorn had foreseen, was overjoyed to have charge of this part of the work.

"I stopped off at Washington, on the way down," added Buck Thorn, "havin' heard that our application had gone through."

"You've got it?"

"Yes."

"I'll tell ——"

"Tell no one yet! Keep it as the first announcement on your first broadcasting day!"

And so it happened, on the following Saturday at eight o'clock, when every man in Ants'-Hole Creek had the head-phones on for the first time, that this announcement came clearly and sonorously, invisible in the invisible ether:

"This is the announcer of Sugarloaf Bald station speaking.

"A decision has been rendered in Washington which is of interest to every one in Ants'-Hole Creek.

"It is as follows:

"The Post-Office has accepted the application made by our Congressman. Ants'-Hole Creek, Buncombe County, North Carolina, has been made a post-office of the second class. Mr. Joseph Medway —whom we know better as Millennial Joe—has been appointed postmaster.

"Mr. Ireton will now announce the program he has chosen for to-night, from stations all over the United States."

In three years, ambition had been reborn and almost twice the acreage was under plow. Agricultural implements abounded, and work animals were in good condition. Every cove farm had its cow.

There had never been a winter without school since radio was put in. A rough log bridge had been thrown across the creek. There was a road into the cove, and Hugh had a little motor-car which Simpson's eldest boy had learned to drive. This car made a weekly trip to Foljambeville, in time to catch the train, which the old team could never do.

As a result of a broadcast talk on recruiting, Cram joined the army, and had become prominent in his regiment as a sharpshooter. He carried a rifle, still, but it was to win medals, not to carry on feuds. Ollie grew more sickly, the weak stock prevailing. Wat Burke became interested in other things than making "moonshine," and his transformation was one of the most substantial achievements of radio.

Millennial Joe was too old and too rheumatic, then, to do more than go from his arm-chair by the fire—beside his crystal set—to the little lean-to built beside his shack for a post-office. There was now a loud-speaker in the schoolhouse, and on the three Sundays in the month when the preacher did not come, there was service just the same, with organ music such as no cove-dweller ever heard before.

Most of the women had sewing-machines; the days of the faded cotton wrapper and the sunbonnet had gone. Dietetic and cooking talks had taught them how to prepare better food, and—sure sign of progress—the piles of tin cans were diminishing. Miss Ferguson lived in the valley, and Buck Thorn's visits at her home were more and more frequent.

Ireton still held an iron hand over the broadcasting, and taxed Hugh's ingenuity to tune in to the places he had chosen. Will was the soul of loyalty; largely by his efforts in the business end, the borrowed capital was nearly all paid up.

The people of Ants'-Hole Creek were not much richer than they were before, for the land was overrun with noxious weeds and it would take generations of culture to ensure good yields. They all seemed richer, however, for the roofs of the houses no longer leaked, fences were kept in repair, and vegetable gardens had become a pride instead of an eyesore.

It was no longer a backwoods settlement of " cove folk," reminiscent of Elizabethan England. It was an American community, and the Promethean fire of progress and of desire for betterment had been brought to it by wireless.

Hugh Cecil was becoming famous. Believing that the use of " tubes " had been encouraged because of the desire for sales, and that " crystals " had been ignored because the profits on them would be small, he did a great deal of investigating into " freak crystal reception " with astonishing results, and wrote extensively for publication.

Already, an official of that great wireless corporation, which did so much for the science and which played so large a part in its present activities and development, had come to Ants'-Hole Creek to offer an important post to the mountain boy.

But Hugh answered:

" There are plenty of good men to do the work in big towns. To my mind, the building up of Radio America has got to be done bit by bit, and the Cove, sir, is my bit! "

THE END