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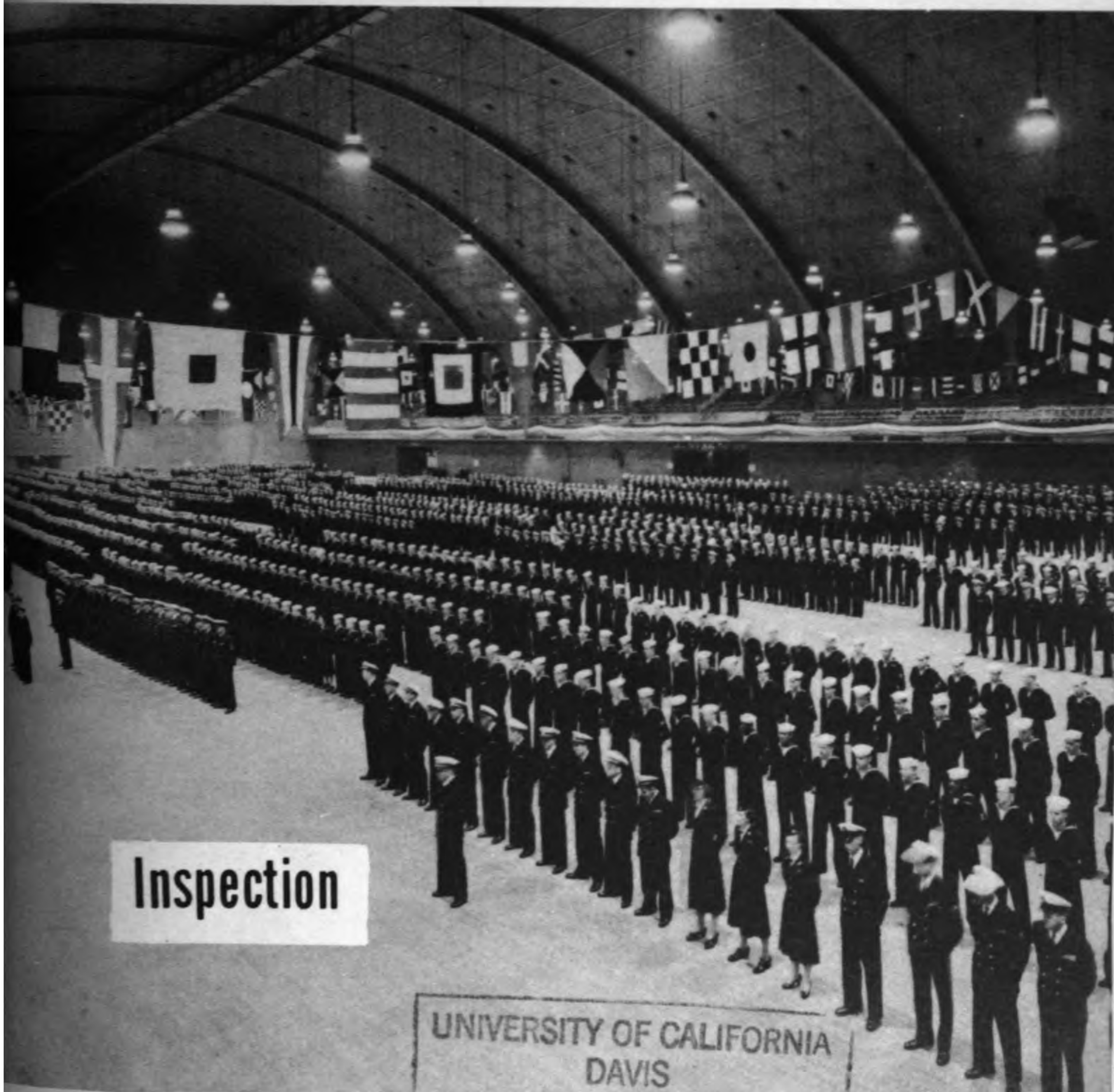
RESEARCH REVIEWS



NAVEXOS P-510

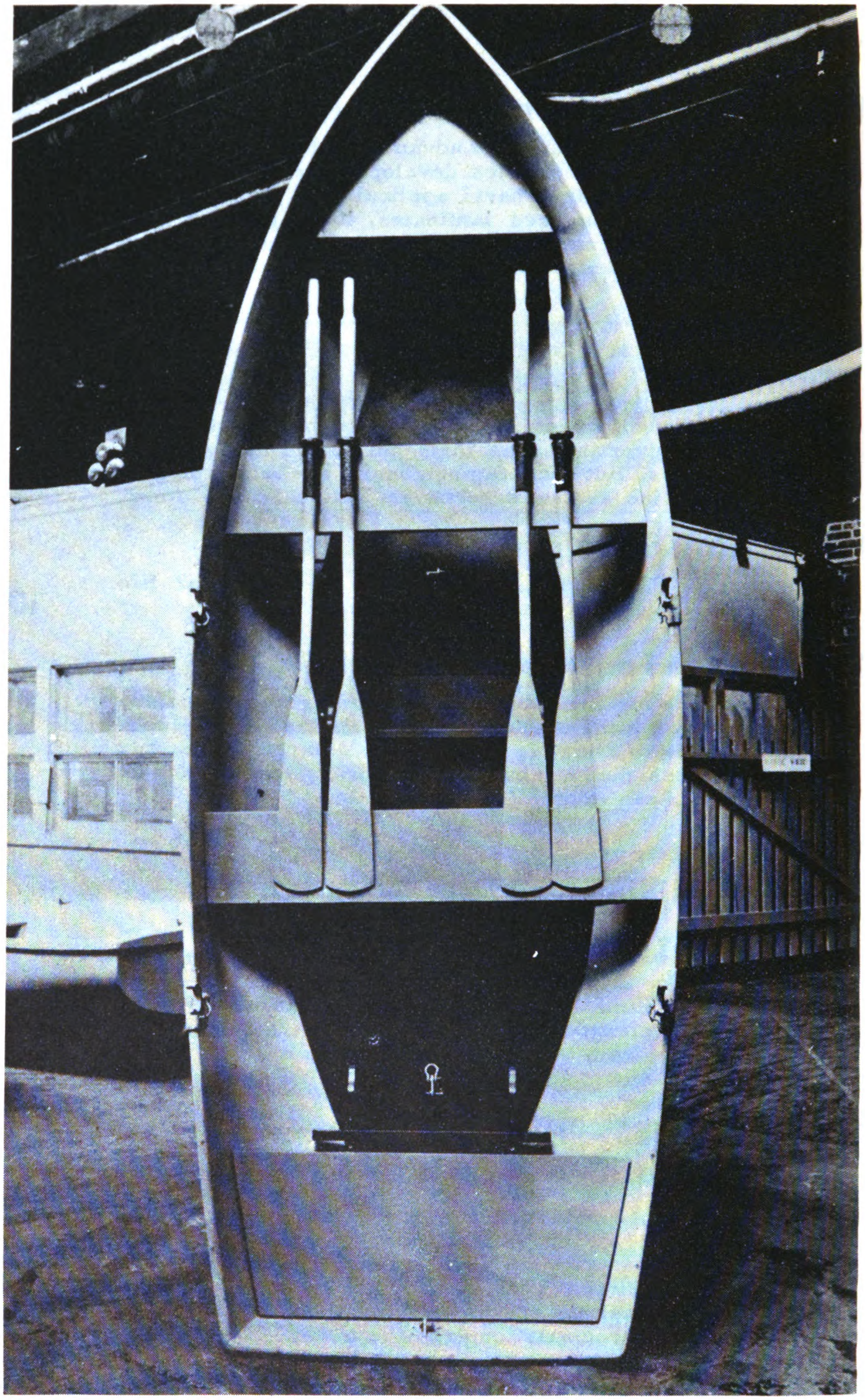
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

COVER PHOTO: This impressive array is the Annual Inspection of the Washington D.C. Non-Pay Naval Reserve, held on 28 April in the National Guard Armory. The Reserve Research Battalion made a creditable showing here.

Research Reviews endeavers to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C.

Approved by Bureau of the Budget, 14 February 1952

In This Issue



This 12-foot wherry was built of plastic by the Puget Sound Naval Shipyard. Over 200 of these have been put into service in the last two years.

The Navy Looks at Structural Plastics

William R. Graner

. . . Materials Engineer in the Materials Development Div., Bureau of Ships, gave a longer version of this article at the A.S.M.E. meeting, April 28, in Columbus, Ohio.

During World War II, a new industry was born as the result of the commercial development of a family of resins known as unsaturated polyesters. The Navy shared and benefited in the rapid progress that took place, and year by year since then has found further application for structural plastics.

When techniques of the plastic industry reached the point where satisfactory results were obtained in bonding or laminating such materials as glass fibers, there was even more opportunity for the Navy to investigate and work out applications. Boat construction, in particular, was a likely field for the use of glass-reinforced plastics. First, there was the needed strength and durability, then there were the other points of advantage such as light weight, simple manufacturing process, and possibility of savings in cost for the end product.

While the plastic boat and its manufacture has been regarded as perhaps the best example of the Navy's use of structural plastics, there are a variety of other applications ranging from shipboard piping to submarine fairwaters. Underlying the use of these materials by the Navy are some basic investigations on mechanical properties. Many a technician from various segments of the industry has contributed to the compilation of fundamental information, and a review of these considerations here will serve to point up the later discussion on the utilization of structural plastics by the Navy.

There are four basic techniques for molding structural plastics with each offering inherent advantages and disadvantages. When it comes to a choice of fabrication methods, the specific application for the structural plastic governs. Glass-reinforced laminates may be sawed, turned, drilled, or tapped, and, in some instances, punched. With such latitude, shapes and forms can be considered for a wide variety of engineering and manufacturing processes.

Mechanical connections may be made by means of bolts or rivets, although field riveting has not yet been accepted by the Navy as a shipyard practice because of danger of damaging the laminate. The minimum edge distance and pitch for bolted connections cannot follow usual design experience with metals; entirely new data must be worked out for the various structural plastics. Related work on fastenings as they apply to these laminates is going forward at the Materials Laboratory located at the New York Naval Shipyard, and as such represents a piece of planned development sponsored by the Bureau of Ships.

Mechanical Properties of Polyester-Glass Laminates

Property	Mat	#181 Fabric	Roving (Fishing Rod Stock)
Glass by Volume(%)	25	45	55
Resin by Weight(%)	60	38	30
Tension(psi)	24,000	40,000	120,000
Flexure(psi)	32,000	60,000	150,000
Compression(psi)	25,000	35,000	70,000
Flexural Modulus(psi)	$1.7x10^6$	$3x10^6$	$6x10^6$
Shear(psi)	17,000	19,000	
Bearing(psi)	39,000	42,000	
Impact Strength(ft.lbs/in.)	25	25	70
Water Abs., 24hr., %	0.4	0.3	0.15
Specific Gravity	1.55	1.75	1.90

Owens-Corning Fiberglas Corp.

In working with plastics where connections are needed, often the best answer is found in a suitable adhesive. Glass mat impregnated with polyester resin has been found satisfactory; among others that prove suitable are asbestos-filled polyester adhesives or epoxy formations.

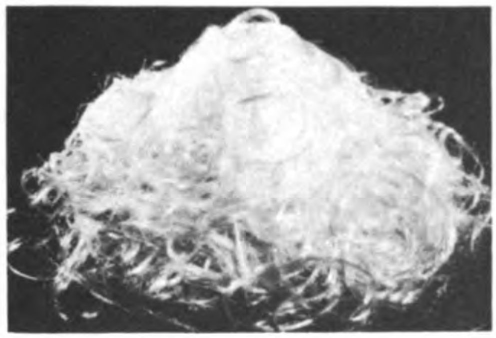
From experience it has been found that bonded joints made under shop conditions may be highly variable in strength. This seems

Material Laboratory
NY Naval Shipyard

TENSILE, FLEXURAL, AND HARDNESS PROPERTIES BEFORE AND AFTER OUTDOOR WEATHER AGING FOR STYRENE CROSS-LINKED POLYESTER GLASS BASE LAMINATE (#114 FINISH)

Aging Period Months	Panama	New Mexico	New York	Canada	Alaska	Panama	New Mexico	New York	Canada	Alaska
	Tensile Strength, 100 PSI, Avg.					Tensile Modulus, 10^6 PSI, Avg.				
0		318					2.33			
1	301	332	--	--	--	2.02	2.22	--	--	--
3	320	320	310	304	324	1.98	2.09	2.08	1.91	2.01
7	302	302	277	298	312	1.83	1.90	1.79	1.62	1.93
12	295	315	300	296	292	1.64	1.86	1.82	1.58	1.64
18	285	305	323	300	299	1.72	1.90	1.99	1.74	1.62
24	281	307	298	293	295	1.75	1.98	1.93	1.67	1.68
30	283	296	306	283	282	1.97	2.32	1.93	1.84	2.03
36	--	--	299	282	300	--	--	2.27	1.99	2.1
Shelf			317					2.62		
	Flexural Strength, 100 PSI, Avg.					Hardness, Rockwell "M" Scale, Avg.				
0		388						111		
1	367	382	--	--	--	105	107	--	--	--
3	324	400	348	398	398	107	110	108	110	112
7	338	373	328	332	369	108	110	109	110	109
12	328	350	339	317	316	106	107	107	106	104
18	305	326	349	293	277	103	109	104	104	103
24	324	363	347	322	284	104	107	108	103	104
30	--	--	340	284	274	104	107	106	103	104
36	--	--	315	281	296	--	--	105		
Shelf			384					113		

Types of glass reinforcement commonly used: above, random distributed mat (weakest type); above right, woven cloth (stronger, but the strength is not equal in all directions); and unidirectional roving (highest strength).

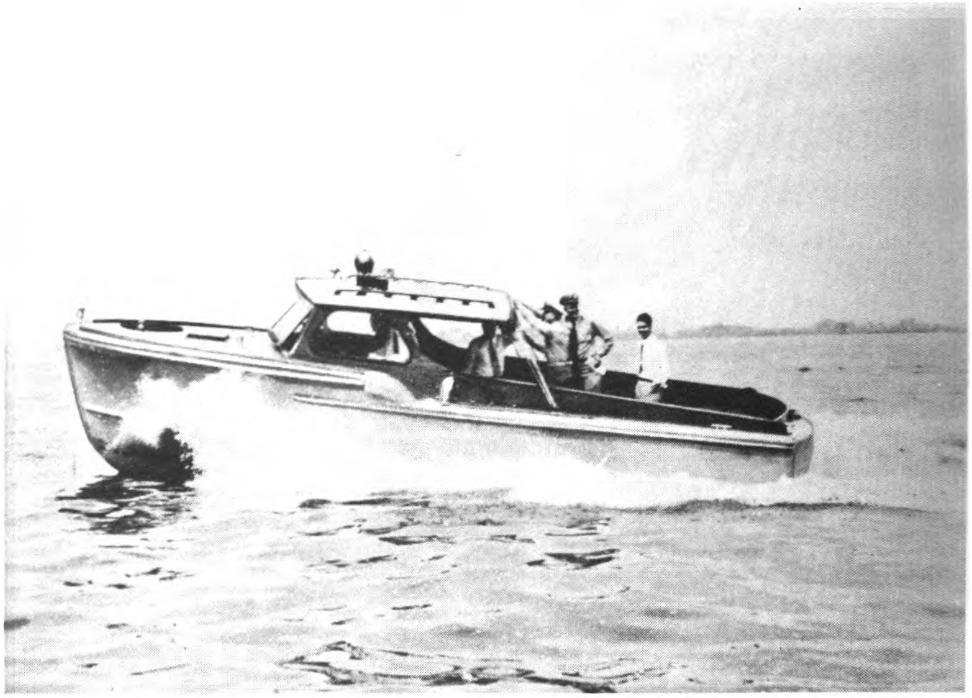


particularly true of room temperature curing conditions. Great care must be taken to obtain a satisfactory joint. Furthermore, bonded joints tend to be susceptible to peeling, and are weak in tension normal to the glue line. The Bureau of Ships currently considers bonded joints without screw reinforcements to be acceptable only in applications where simple shear stresses are involved.

The tendency of glass-reinforced laminates to lose strength under humid conditions or after water immersion has been a particular problem in Navy applications. This undesirable weakness is related somewhat to the degree of adhesion between glass and resin. To improve the adhesion, work has been done by the Air Force on "sizings," and new ones have been developed that exhibit 90 percent wet strength retention as compared with the 50 percent shown by #114 sizing that has been in use for several years.

It is characteristic of polyester glass laminates that strength decreases when the temperature increases. An index for heat resistance is "Maximum Operating Temperature" (MOT) which is defined as the highest temperature at which a laminate will retain 50 percent of its room-temperature strength. Laminates containing general purpose resins have a MOT somewhere around 100°C. Recently special resins have been developed which bring the MOT range of laminates up to 150-200°C.

Polyester glass laminates are, of course, completely corrosion resistant. They are weather resistant, chemical resistant, and resistant to sea water and sea life. The effects of three years' exposure to five different climatic conditions are recorded in the table opposite.



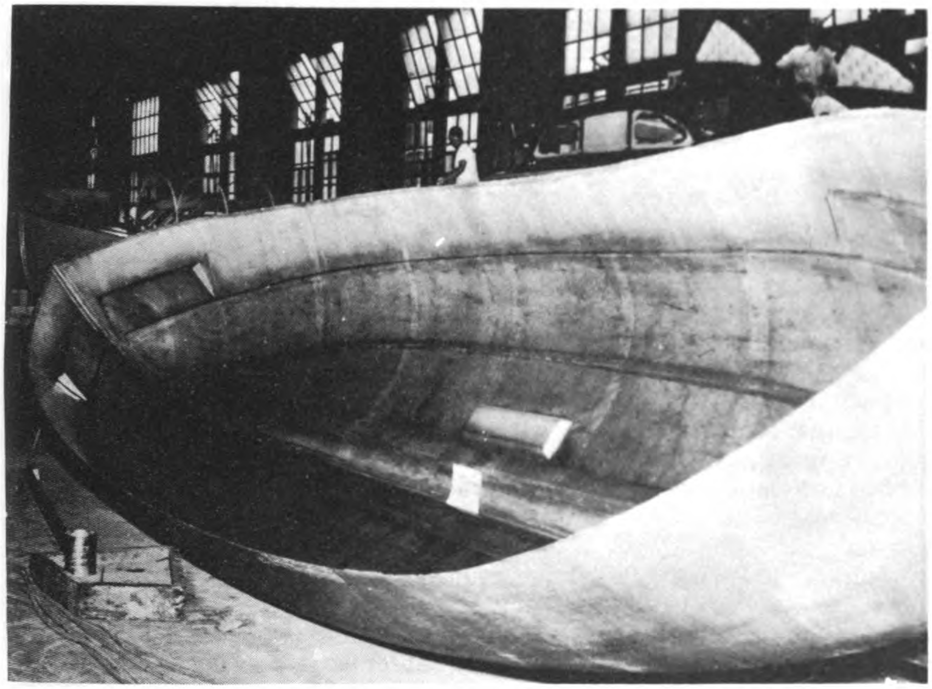
One of four 28-foot plastic boats delivered to the Navy six years ago.

While, in general, flexural strengths do show a significant downward trend, it should be noted that after exposure to the dry climate of New Mexico, this is not the case. It may be, therefore, that the decreases are evidence of "wet" strength reduction previously mentioned. Darkening of samples may be due to soot deposits. As a result of this program, it has been concluded that the climate of a seaport such as New York is most severe on plastic materials.

Samples immersed in sea water for over one year have shown that, while polyester-glass laminates foul readily, they are completely unaffected by marine life such as marine borers, which will chew right through a wooden boat. The Fish and Wild Life Laboratory has found, too, that the material is completely resistant to rodent attack.

Because of their chemical resistance, the laminates are finding wide use as a liner for tanks. They are resistant to dilute acids, aliphatic hydrocarbons, and various fuels. They are attacked by concentrated acids and alkalies. It is always advisable to determine the effect of the chemical on the specific laminate used over the expected operating temperature range, since the chemical resistance of polyester resins does vary. The materials have also been found to have far better resistance to sea water erosion than many metals at velocities up to 70 feet per second, the highest velocity tested.

The economic factors involved in the use of these materials for structural purposes include consideration of first cost (including basic materials, molds, fabricating and finishing), replacement costs, ease of repair, and ease of making adjustments or modifications. First cost may be higher than that for other materials. However, this is not



Twenty-six foot plastic whaleboat made by the Norfolk Naval Shipyard.

always so. In many cases, ease of fabrication tends to reduce cost considerably. Furthermore, because of the durability of the laminate, it is usually in competition with the expensive and critical non-corrosive alloys. Low replacement requirements and ease of repair are also very important factors in naval applications. Reinforced plastic items may be very simply repaired, through use of the same materials employed in the original construction, without the application of heat.

Now, let us look at why and where the Navy is interested in applying structural plastics. The "why" may be quickly summarized by reviewing the unique combination of characteristics of these materials: (a) light weight, (b) high strength:weight ratio, (c) durability, (d) non-magnetic properties, (e) resistance to marine life, (f) erosion resistance (70 feet per second velocity), (g) dielectric properties, (h) ease of repair, and (i) corrosion resistance.

The "where" includes the following: (a) boat hulls, (b) shipboard piping, (c) submarine fairwaters, (d) minesweeper floats, (e) shipboard superstructure, (f) waveguides for electronic applications, (g) sanitary plumbing fixtures, (h) high-pressure gas storage cylinders, and (i) miscellaneous applications such as carrying cases, compass covers, sea water scoops, bunks, etc.

One of four 28-foot plastic boats, delivered to the Navy some six years ago, is shown on the opposite page. The hull was made in an aluminum female mold by bag molding techniques. Two boats were framed with wood covered with laminate, but this proved unsatisfactory because absorbed moisture caused the wood to swell, thus cracking the laminate. Two other boats framed with aluminum are still in service. A 26-foot whaleboat (shown above), made by the Norfolk Naval Shipyard, is a product of another method of fabrication—vacuum injection. Stiffeners or mountings consist of precast laminates which were inserted into the boat layup before impregnation. Box-type stiffeners have also been used in boats, employing a light-weight core material such as cellular cellulose acetate around which the laminate is built up.

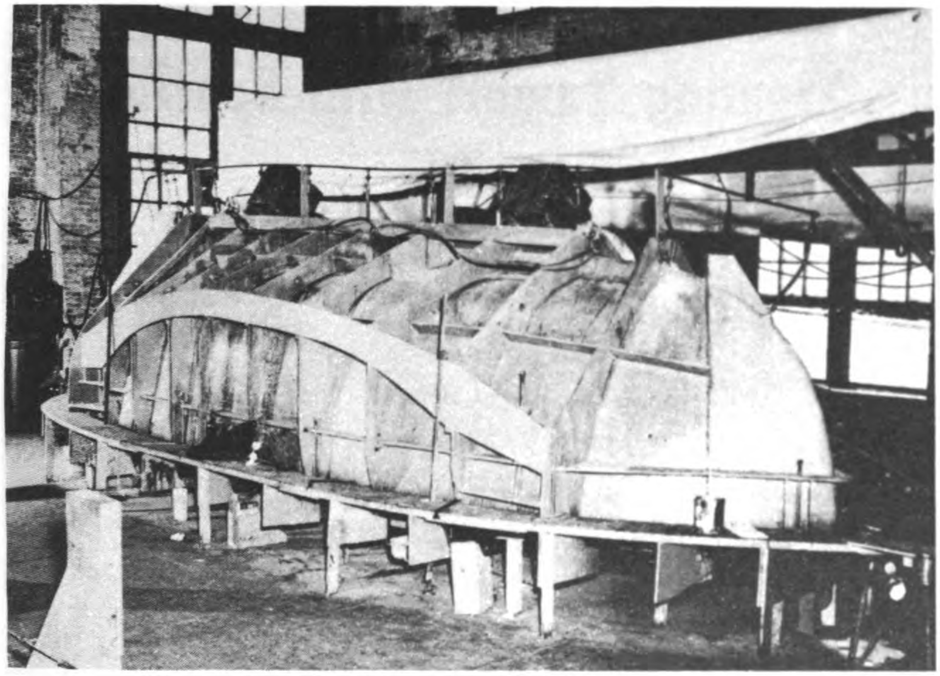
A 12-foot wherry (see frontispiece), built by the Puget Sound Naval Shipyard, is the only craft on which we have had fairly extensive service reports. Over 200 of these have been put into service in the last two years. As a result of this experience, thwart brackets and breasthooks have been added, thwart connections strengthened, and the hull redesigned to include glass cloth as well as mat in the layup. During the past year, the Navy has also purchased a variety of other craft, ranging from 9 feet to 36 feet in length. Experience to date indicates that plastic boats are lighter but not cheaper than wooden boats. However, it is expected that there will be a tremendous saving in maintenance and replacement costs. Ease of repair is also an important feature.

Principal problems involve development of adequate specifications and performance tests. Furthermore, design of larger boats is hampered by lack of standards and reliable design data. Recently, attention has been directed toward the possible use of sandwich-type, honeycomb construction as a means of reducing weight and improving stiffness.

To test these materials for use in shipboard piping, about 90 feet of pipe was installed on a destroyer escort over 20 months ago. It was put into the 150-psi salt-water flushing systems, located in various sections where the pipe would encounter severe service. All of this pipe, with the exception of a section over the boiler which has become coated with salt deposits (indicating slight porosity), is still in good condition. At present, a complete installation of reinforced pipe in the cold water lines of a minesweeper is being finished. Bronze deep-socket type fittings are being used with epoxy adhesive to bond metal to plastic.

This installation has revealed two unanticipated shortcomings: (1) it was found that various commercial pipes would not withstand a proof test pressure of 600 psi for 24 hours although they would probably withstand much higher pressure for a very short time, and (2) that this pipe, in contact with water, has surprisingly poor heat resistance. These shortcomings may possibly be overcome by the use of the new glass sizings. If installation and production difficulties are overcome, as seems likely, the use of plastic pipe promises considerable weight savings (.45 pound per foot for plastic as compared to 3.65 pounds per foot for steel 2-inch pipe, for example), and it should be competitive in cost, ultimately, with metal pipe. Furthermore, it is completely non-magnetic, corrosion resistant, and exhibits outstanding erosion resistance. Principal limitations are flammability, the fact that it cannot be bent, and the present lack of commercial sources for competitively priced, reinforced plastic fittings having satisfactory strength.

Storage tanks of the type used in minesweepers are also under investigation. Tanks ranging in size from five to 4150 gallons, usually made of monel metal or bronze, are required for this non-magnetic application. Five shipsets of tanks are now being purchased for service evaluation. In addition to replacing critical materials and being



Twenty-six foot plastic whaleboat, with mold closed and ready to cast.

completely non-magnetic, these tanks promise to be cheaper and will save approximately 40 percent in weight. Problems involved have centered around lack of design standards and experience. Unlike tanks of regular elliptical or circular cross-section, which may be designed on a strength basis, these tanks are irregular in shape with flat side conforming to the contour of the ship. Consequently, deflection rather than strength is the controlling factor, and many internal stiffening or tension members have to be employed to break up the unsupported panel areas.

Another interesting application being investigated is the submarine fairwater. The fairwater, now made of aluminum, surrounds the projecting superstructure and provides a smooth streamline. Electrolytic corrosion at the joints between fairwater and hull is a serious problem. Two solutions to this problem are now being explored. The first involves complete insulation of the fairwater from the hull by means of reinforced plastic straps and separators. The second involves construction of an all-plastic fairwater. Since wave loading has been estimated as high as 1000 pounds per square foot and portions of the aluminum fairing have been known to carry away, it can be seen that this is not a simple structural problem.

In an effort to be of assistance to the designer, certain limitations and problems involved in the application of structural plastics have been pointed out. Structural plastics, as we know them today, are a challenge to the progressive designer; a challenge to use materials which offer a combination of unique advantages found in no other materials; a challenge to use them as they should be used, where they should be used. It will require greater effort, more personal attention, perhaps, but the end result, if a proper application is selected, should be a better, more durable product.

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Treating Tumors with Neutrons

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. . . Chairman of the Medical Department, Brookhaven National Laboratory

The readers of Research Reviews are all more or less informed on the role of neutrons in the detonation of atomic bombs. Neutron capture is the trigger mechanism for the fission of uranium, which in turn produces more neutrons, and under suitable conditions the resulting chain reaction results in an explosion of almost incredible violence. Somewhat less well-known are the possibilities of using similar reactions in the treatment of human cancer.

It has been discovered that there are many substances which when injected into the blood stream readily enter certain kinds of brain tumors, but which enter normal brain tissue very slowly if at all. It was found at the Massachusetts General Hospital that borax is one of these substances. This is of especial interest because borax is about 10 percent Boron, and one of the isotopes of Boron, B^{10}, has what is called a high capture cross-section for thermal neutrons. When the B^{10} captures a neutron it becomes very unstable and disintegrates into two lighter particles, an alpha particle and a lithium nucleus.

As in the fission process, this splitting releases energy, most of which appears as the kinetic energy of the resulting particles. This reaction is in common use as a means of detecting neutrons. If it can be caused to occur inside a tumor, a dense ionization is produced along the paths of the particles and the net result is a form of selective radiation of the tumor. All that one needs besides a method of loading the tumor with Boron is a beam of neutrons.

A suitable source of neutrons is available from a nuclear reactor. The reactor at the Brookhaven National Laboratory was designed for research applications, and it is possible to place a patient's head in a neutron beam without exposing the rest of the body to dangerous amounts of radiation. A series of ten patients with brain tumors have been given this kind of treatment, some of them getting up to four treatments each. The patients had all been operated upon previously and had been found to have tumors with satisfactory uptakes of injected Boron. Although only one of these patients is still living, their clinical courses have been such as to encourage further work.

West face of the Brookhaven nuclear reactor. The steel and concrete plug in the right foreground is used to seal off openings in the top of the reactor. The facility for treating patients is on top and cannot be seen.

There are a number of unsolved problems and possibilities for improvement which are providing fertile fields for research. These include such problems as measuring the radiation dose rate inside the tumor during treatment. Ways are also being sought to improve the efficacy of the treatments by increasing the amount of Boron which the tumors take up. There is also a search being made for compounds of other elements which might provide even more local radiation than can be obtained from Boron. Among the possibilities are Lithium, some of the rare earths, and Uranium. In general the compounds of all of these possibilities are so toxic that only small amounts can be administered.

But this is a field in which much remains to be learned, and there are good reasons for expecting that diligent search will turn up a suitable compound. Research of this sort brings together the special talents of people trained in many fields—medicine, physics, chemistry, and electronics are all involved.

Although the treatment of brain tumors is primarily a medical department project, several non-medical members of Naval Reserve Research Company 3-9, which meets at the Brookhaven National Laboratory, have contributed to the project in one way or another.

Who's Who in Naval Research

Captain C. P. Phoebus

The Naval surgeon now occupying the ONR spot recently vacated by Captain Shilling—Special Assistant for Bio Sciences—is Captain Clifford Preston Phoebus (MC) USN. His job is to advise the Assistant Chief for Research and the Science Director concerning the programs in the medical, biological, and psychological sciences and to act as liaison officer with other agencies working in these fields.

Captain Phoebus was born in Baltimore, but grew up in the close-in suburbs of New York, graduating cum laude from a Brooklyn high school. Having determined to be a doctor, he did his pre-med work at Lafayette ('32) and completed his medical training at Jefferson Medical College in Philadelphia (1936). He served his interneship in Danville, Pa. and then competed successfully in the examinations for the Navy Medical Corps. He was commissioned LTJG, USN, in August 1937.

Thence through the war, Captain Phoebus alternated between sea duty and shore duty, but with a good deal more variety than comes the way of most Navy doctors. Quite early he bent his professional career towards aviation medicine and went through every course given by the Army and Navy along that line. His experience has included service aboard carriers, on the staff of a major fleet, in air bases, and at Naval dispensaries. His major wartime duty was with Fleet Air Wing 15—first at Norfolk and then in North Africa. He later took flight training and received his Navy wings. (He considers this a "must" for an aviation-medic; only a flyer can understand the problems of flyers.)

From 1951 to this past June he was Head of the Aviation Medicine Branch of BuMed's Research Division, with additional duty as aero-medical officer for ONR's Air Branch, so he is no stranger to ONR and no stranger to research. (His pet research challenge is how to keep the tremendous noise of jet engines down to limits humans can tolerate.)

Captain Phoebus is married to the former Miss Bernadine Schultz, whom he met while he was interning at Danville, Pa. They live in Falls Church and have three young boys. His favorite off-duty pastimes are golf and swimming, and in the latter he is an expert. In his college days he was a champion swimmer, and now he is proud of his coaching ability; he had each of his sons swimming by the time they were three. (ATD)

Tailor-Made Foam for Crash Fire Fighting

R. L. Tuve

. . . Head of the Engineering Research Branch, Chemistry Division, of the Naval Research Laboratory

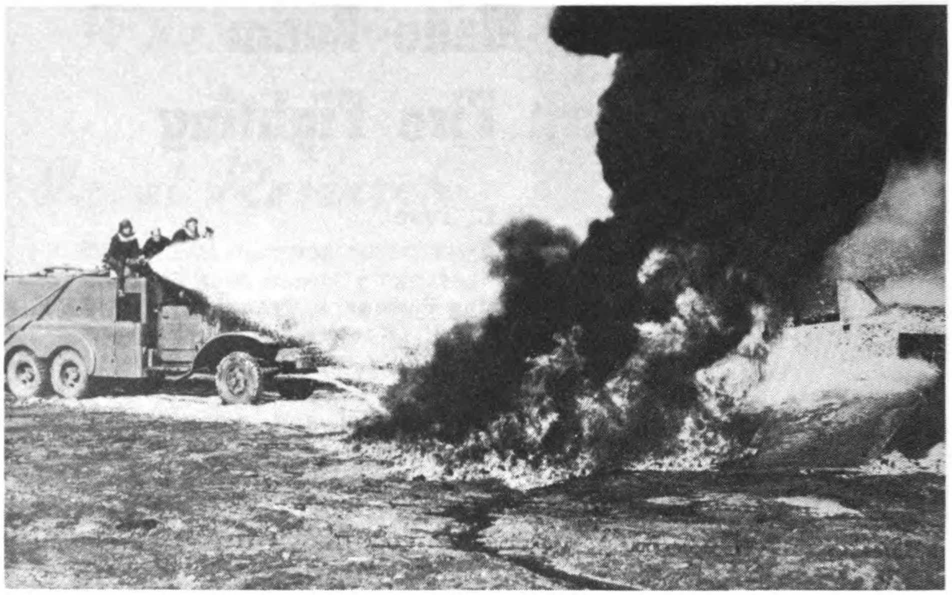
An efficient, fast, non-toxic, foolproof, and cheap agent to control aircraft crash fires and guarantee quick, safe rescues may never be entirely within the realm of possibility. In fact, probably the most we can hope for is a slow step-by-step progress, with inevitable compromises along the way. The material presented here is believed to represent one of these steps.

Mechanically produced foam, or "air foam," of one type or another has come to be regarded as a first line of defense for fighting aircraft fires involving gasoline fuel. The flexibility of this extinguishing agent, its effectiveness per pound of weight, and the permanence of extinguishment easily justify this viewpoint.

To investigate the part played by mechanically produced foams, let us go back to 1943 when one of the earliest experimental crash fire-fighting test programs was being conducted at the Naval Air Station in Jacksonville, Florida. At that time, there was still a prevalent feeling that high-pressure water fog and water streams could blast away the fire from the pilot's compartment and shield him during rescue. Furthermore, there was no device available for gently spreading a large shower of foam particles on a burning gasoline area. The idea of such a "snow-shower" mechanism sounded exceedingly attractive to several of us who were present at a meeting in Jacksonville.

To test this idea, we rigged a standard Navy all-purpose nozzle with its internal impinging jets on the front of a truck (shown on next page) carrying a premixed foam-forming solution. The foam produced by this device was very watery, but the widely dispersed pattern was a great improvement in rapidly forming a blanket over much of the burning area. With knowledge gained from these tests, NRL helped to design the BuAer fog-foam and foam-gun crash rescue trucks FFN-3 and FFN-5 which were put into use in 1944 and are still the principal crash units used today at naval air stations.

A short time later, a need developed for some means of spreading large quantities of foam over wide areas in the hangar-deck space of an aircraft carrier. This was necessary to combat gasoline-fueled conflagrations arising out of suicide-plane attacks such as those experienced by the carrier FRANKLIN. Again the wide-angle, dense, "snow-storm" discharge of the fog-foam fire-fighting system (an NRL design) has since turned in a noble record of gasoline fire extinguishments and rescued personnel.



Early dispersed-pattern foam test

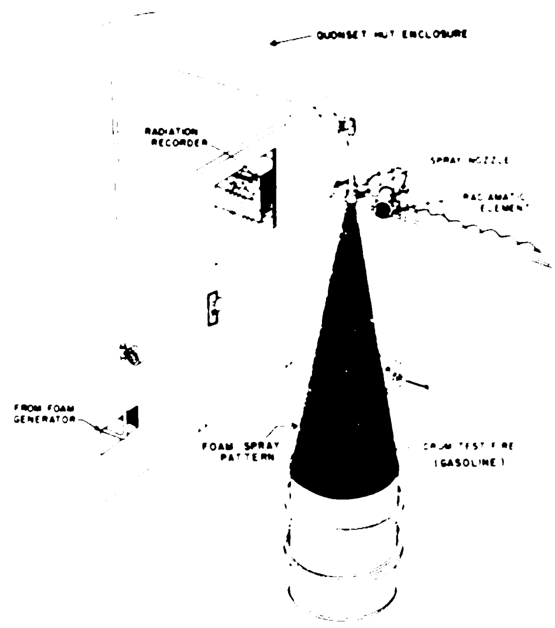
In 1947 the Air Force ran a series of crash fire tests, showing to their satisfaction that high-pressure water fog was not capable of doing the complete job of extinguishment and rescue. Their further experimentation conclusively proved that the dispersed, dense discharge of wet foam from the fog-foam type of nozzle was superior to other available devices.

During the last five years, several different types of crash fire-fighting trucks which use foam as the primary agent have been developed and produced by industry. Most of these utilize the fog-foam nozzle to obtain a quick coverage of heat-removing wet foam as soon as the truck reaches the burning fuselage. Some exceedingly rapid rescues and quick extinguishments have been performed through use of this equipment.

It is important to realize that the impinging-jet fog-foam nozzle produces only one type of foam having certain characteristics. Its discharge is a wet, sloppy foam, quite fluid on a burning surface, and capable of flowing together over a footprint or dirt depression. Fog foam is not a stable foam; it reverts to its constituents, air and water, in a relatively short time, because of its low ratio of air to water—that is, its low expansion. It is difficult to produce good mechanical mixtures of air and water, regardless of the foam-forming concentrate used, when one attempts to mix small proportions of air with a liquid.

The question uppermost in our minds for the past three or four years has been: What would the comparative efficiency of foams other than fog foam be if they were applied to the fire in the same dense "snow-storm" dispersed pattern, using the same amount of water for making foam? In an attempt to answer this question, several simulated fire tests were necessary.

We started out on a miniature scale. The fires were started in an open-top oil drum with a shower head above the surface through which foam was directed uniformly over the burning area. (See drawing of apparatus, right.) Percentage by volume of air (expansion) and "flow ability" (viscosity) of the foam were systematically varied with each fire test. Our standard of measurement was the rate at which the flames were reduced, as indicated by a radiation-measuring device located in one corner of the fire-test room.

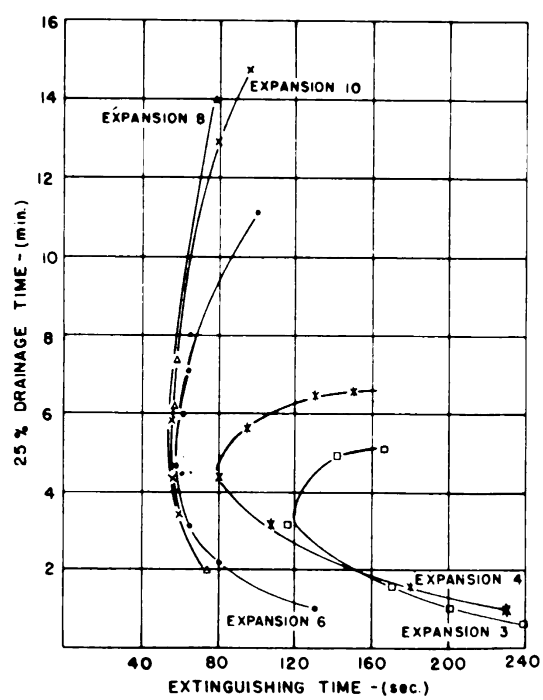


Early spray apparatus

The family of curves below shows the results obtained after many carefully standardized tests. Of special note is the decrease in extinguishing time as foam expansion is increased. This effect appeared to be independent of the viscosity, measured as the 25-percent drainage time, of the foam. In tank fire fighting the more viscous foams are less efficient than fluid ones, simply because they don't flow fast enough across the burning surface. But this problem, of course, did not exist in the dispersed-pattern addition of foam.

Because our scale-size experimentation, using the open-top oil drum, was too small to allow any final interpretation or generalizations, we progressed to a large steel tray in an open field. The tray, 20 feet square by 4 inches high, contained a 2-inch layer of mud to prevent warping, over which we poured one-half inch of hi-test gasoline motor fuel.

A mobile foam generator capable of producing almost any type of foam was designed (picture on next page), and suitable foam-distributing nozzles were used to apply the foam gently and uniformly over the entire surface at once. The apparatus was used in test after test in exactly the same manner, regardless of the expansion or viscosity of the foam, in an attempt to duplicate current



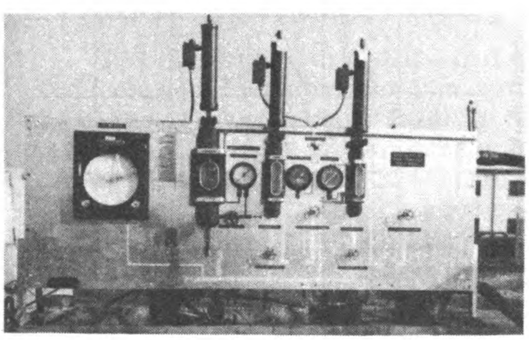
Drum fire-extinguishment tests

fire-fighting turret-nozzle, foam-application techniques. (The standardization of this test was more complicated than described here.) Results of the entire test series are averaged and plotted on the graph opposite. It can be seen that foams with expansions of from 10 to 12 are superior in their speed of flame knockdown and control when applied in the dispersed pattern now widely used for fighting crash fires. The effectiveness does not seem continued above an expansion of 12, however, probably because of the extreme lightness and stiffness of such foams. Even when compared with ordinary foams of the expansion-8 class, such as those produced by a standard long-barreled foam nozzle, a 30-percent-faster flame knockdown can be achieved with homogeneous, small-bubble foams of expansion 10 to 12.

Another important factor found in these tests was the ability of foams with expansion 10 to 12 to resist breakdown during heat attack and thus prevent reflash. If a tongue of flame remained in one corner after virtual extinguishment of the gasoline, it did not burn back with the rapidity shown when foams of lower expansion were used.

These studies also indicated that if a practical device could be found for producing higher-expansion foams from standard protein foam liquid, there would be a distinct possibility of measurably decreasing the rescue and extinguishment time of contemporary crash equipment. Unfortunately, present foam nozzles which aspirate air into the water stream normally do not produce the foam expansion desired, nor is the foam under a sufficient pressure to give a dispersed pattern with good range when forced through a foam-distributing nozzle.

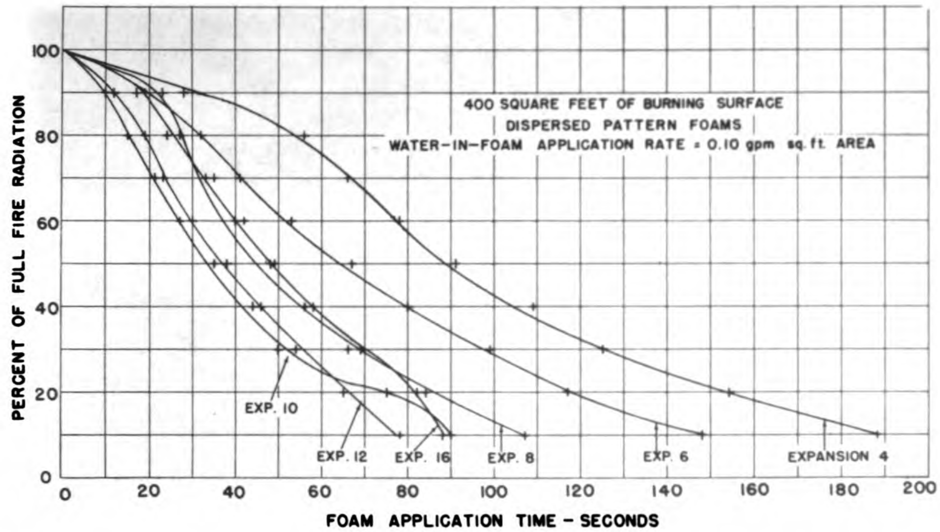
The mechanical-pump method of producing foam appeared to be an alluring possibility. NRL's positive-displacement rotary-pump foam generators for oil and gasoline tank fire extinguishment have been used quite satisfactorily by the Navy for the past seven years.* A similar type of foam-making pump—the flying-vane type, employed by the British RAF for crash work—was imported to NRL for engineering tests to determine its suitability for our purpose.



Autocontrolled foam generator

Much experimentation was required to adapt the British-type pump to our air-foam specifications. We succeeded, however, in varying its performance to give a "tailor-made" foam with an expansion of 11.3, a 25-percent drainage time of 25 minutes, and a production of

*R. L. Tuve, and H. B. Peterson, "A Study of Some Mechanical Foams and their Use for Extinguishing Tank Fires," NRL Report 3725, Aug. 1950.



Gasoline fire-extinguishment process measured by fire radiation (average values of varied foams)

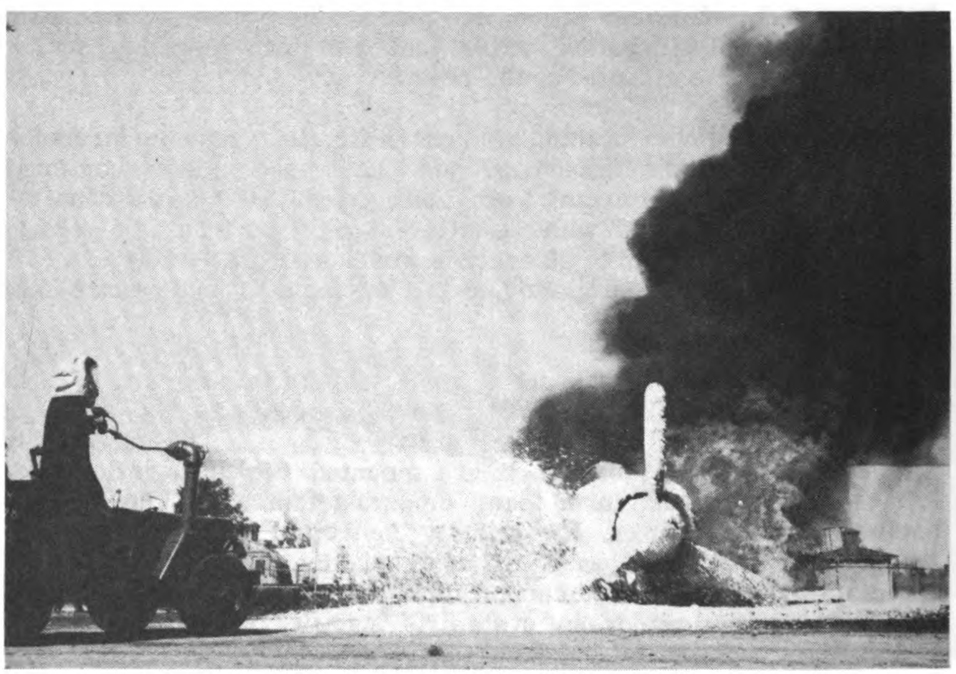
1200 gallons per minute of foam with a 60-horsepower engine. In order to test our laboratory results we mounted this pump on a jeep chassis and made the construction changes necessary to transform it into a foam rescue vehicle. The finished product is shown at top of next page. The foam distributor on the upright pipe on the starboard side of the vehicle is piped directly to the foam pump with 3-inch tubing and operates on the principle of a garden hose nozzle. A center plate moving in and out of the center fixed orifice gives the operator complete control over his foam pattern, from a 40-foot solid cone with only 20 feet of reach, on up through a "bushy-tailed" discharge stream, to a solid stream of foam capable of discharging on a target 90 feet distant with only 9 pounds per square inch nozzle pressure. The foam pump under the 240-gallon water tank and the 20-gallon foam-concentrate tank is mounted at the rear.

During a number of simulated crash fire tests, the performance of this jeep was quite satisfactory, and we have become more confident concerning our experimental foam-testing results. We can consistently perform "rescues" with the tailor-made foam from this vehicle in operation times of 15 to 25 seconds where a single-engine aircraft is fully involved from propeller to tail surfaces in 600-square-foot gasoline fires.

We went a step further in the application of tailor-made foam to crash fire fighting. We designed a truck (see page 17, top) from an existing chassis used by NRL for oil fire-extinguishment tests made in Findlay, Ohio in 1945. On it are mounted two 3000-gallon-per-minute British-manufactured foam pumps together with the necessary engines and liquid tanks. Electrically controlled nozzles of the jeep type are positioned forward. All foam-making controls and nozzle directors are in a screened cockpit topside from where the crew chief operates. A public-address system is installed for crew direction and rescue "talk-out." Although this truck compares in size and

NRL's "Jeep Foam Rescue Truck"

The "Jeep Foam Rescue Truck" in operation



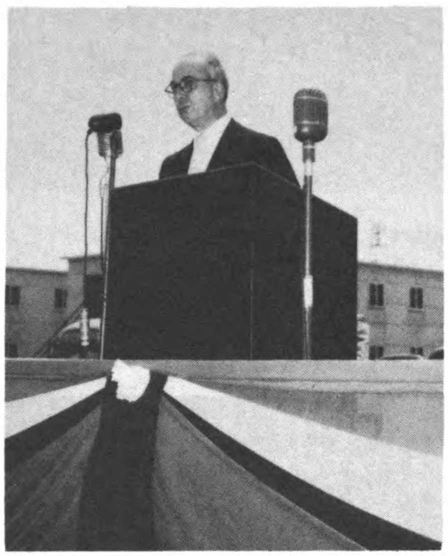
The "Big Squirt"

The "Big Squirt" in operation

materials with contemporary crash trucks, it can spray over 6000 gallons of foam per minute from its nozzles. The nozzles are instantaneously adjustable in any position, and to any pattern, from a wide solid shower to a solid stream capable of shooting 180 feet distant. Large hose handlines on each side of the truck are available for cleanup. The crew chief throws an air-operated valve to give each handline a supply of about 1200 gallons per minute of foam.

The practical developments of this research will be used by both the Bureau of Ships for carrier-based aircraft and the Bureau of Aeronautics for air-station crash fire protection. They will be in the form of suitably designed mobile units with requisite chassis designs. How effectively they will extend aviation safety will be answered only by future applications of the principles involved.

NRL's Thirtieth Anniversary Commemorated



On the afternoon of July 2nd, ceremonies were held on the grounds of the Naval Research Laboratory to commemorate the organization's 30th birthday. More than a thousand guests were on hand not only to hear the speeches and participate in the program, but to see firsthand what the Laboratory is doing. Many of the buildings were open with equipment in full display.

The ceremonies began with a few words of welcome by CAPT W. H. Beltz, Director of the Laboratory. The main address of the ceremony was given by Lewis L. Strauss (left), newly appointed Chairman of the Atomic Energy Commission. A number of newsmen and photographers were on hand to report on this first major speech by Mr. Strauss since his elevation from Special Assistant to the President to Chairman of the AEC.

RADM C. M. Bolster, Chief of Naval Research, presented awards to nine employees of the Laboratory who had been in the original group that staffed the Laboratory 30 years before.

A special exhibit of NRL scientific work with emphasis on "push button" effects attracted most of the guests before the end of the afternoon. Because the NRL Recreation Club held an "open house" and, among other things, opened its swimming pool to guests, there were times of relaxation on the hot July 2 which perhaps helped to sustain the interest of the people as they visited buildings and viewed scientific accomplishments until the whistle at six o'clock sounded "time to go home".

The Undulator -- A New Millimeter Wave Generator

H. Motz

. . . Microwave Laboratory, Stanford University, has a broad background of research at the Universities of Besançon, France, Dublin, Ireland, and Oxford.

There is hardly any kind of electromagnetic radiation which has not found important applications. We use X-rays in medicine and metallurgy, light for seeing—either unaided or aided by microscopes and telescopes, infrared light for extending vision through fog, microwaves for radar and television, and radio waves for communication. To the physicist, all these forms of radiation are of the same nature, and differ only in wavelength, ranging from the shortest (γ-rays and X-rays) to the longest (radio waves).

The yardstick of comparison is, in the last analysis, the size of the human body. One should perhaps say that a more objective yardstick is the size of the atom, but of course the two are closely related. The atomic comparison scale, however, points to an application common to all types of electromagnetic radiation: the study of matter by means of spectroscopy.

In this vast world of radiations there exists, as it were, a small but uncharted continent, situated between the infrared and microwave regions: The millimeter wave range. Let us try to explain how this has come about. Radiations of wavelengths longer than a millimeter are emitted by man-made objects: resonators, antennae, combinations of coils and capacitors. Radiations of shorter wavelengths, on the other hand, are emitted by natural objects: molecules, atoms, and nuclei. While it is possible to make objects the size of a millimeter, human size makes it very hard to construct such objects with detailed features as accurately as larger ones. Who would like to scale down a wrist watch to 1/100 of its customary size? Yet that is almost literally the problem. Shown at the top of page 21 is a magnetron (developed by Columbia University) which produces waves in the 3-millimeter band. It is likely that the limit of human resourcefulness has been reached in devices of this type, and that further "scaling down" is almost impossible.

Now one may ask what is wrong with generators using "natural objects" as emitters. This needs a little explanation. Wave trains emitted by atoms or molecules always fade out after a small number of oscillations. In radio communication and radar we use man-made oscillations, i.e., long wave trains comprising many thousands of wavelengths. "Natural" wave trains, however, are always short. They come about by random excitations of molecules or atoms, caused by their irregular motions at elevated temperatures.

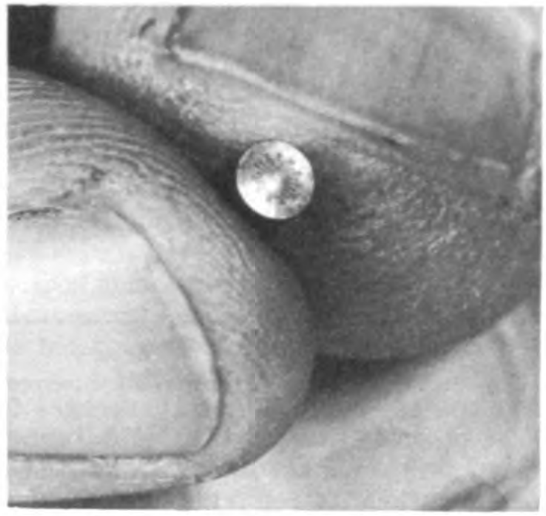
It can be shown by means of a very important mathematical theorem, Fourier's Theorem, that a short wave train is equivalent to a whole bundle of long wave trains of different frequencies (or wavelengths). Waves emitted from "natural emitters" have such frequency components which constantly change in phase as a function of time. Such radiation is incoherent. It would be of great value to have a source of, let us say, coherent light waves of one single wavelength (or at least a very narrow range of wavelengths). A light ray could then serve as a carrier of musical or television programs: suitably modulated, a light beam could carry a million programs simultaneously. All this and much more could be done if it were possible to make a large number of atoms radiate light coherently, i.e., if the times at which different atoms emit their light waves could be synchronized.

It is well known that light, and indeed any type of electromagnetic wave, exhibits the phenomenon of interference. That is, if two trains of waves travel together in such a way that the positive crests of one occur just where negative troughs of the other are situated (and vice versa), cancellation of intensity occurs. In various optical instruments interference fringes are thus produced. To obtain such fringes of light and darkness, light from natural sources has to be split up into components (by means of half-silvered mirrors, etc.) which are then made to interfere with each other. One might say that light from a "natural source" interferes with itself, but light emitted at one moment does not interfere with light emitted much later from the same source, nor with light from a different source. The reason is, of course, that the phases of the different frequency components are constantly changing.

Now let us consider the situation inside an incoherent light emitter (e.g., the filament of an incandescent lamp). The individual atoms emit at random times; hence by interference a large amount of cancellation of intensity must take place. Since light is a form of energy and energy cannot be destroyed, it must be conserved in the form of atomic and electron motion. But if the atoms could be made to radiate in phase, the emission of radiation would be greatly enhanced, and we could obtain much more efficient light sources. Emission from incoherent sources is much less efficient than emission from coherent sources.

Thus there are two guiding principles to be followed if we desire to find a source of millimeter waves. It should be, if possible, a coherent source, or an array of sources, spaced with the periodicity of the millimeter wave. Yet we want to avoid methods involving physical structures of small size, or devices with tiny features that are difficult to make with the necessary accuracy.

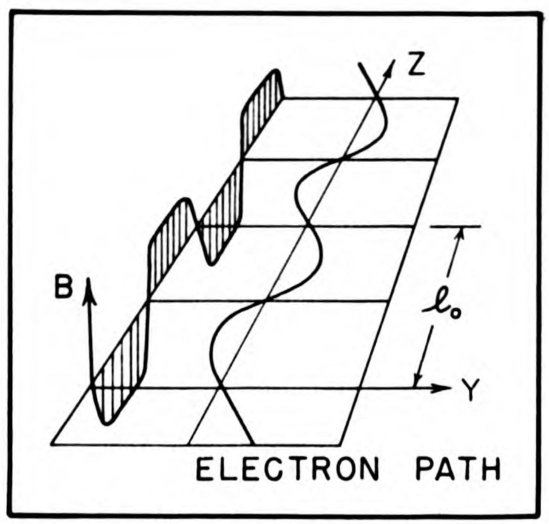
The first basic idea underlying the undulator is to use, as it were, artificial atoms. The orbits of atomic electrons are not under our control, and it seems difficult to align them so that they radiate in phase. But in electric or magnetic fields, electrons can be made to move in prescribed orbits. Wherever the motion is accelerated radiation is emitted. Moreover, if the accelerated portions of the orbit were spaced in regular sequence a distance of the order of millimeters apart, millimeter waves would be emitted. This arrangement seems quite feasible, but the scaling-down problem appears to be still unsolved; the structures by which the spatially varying fields must be produced seem to require spacings which are again of the inconvenient millimetric dimensions. Here the second basic idea comes to our assistance.



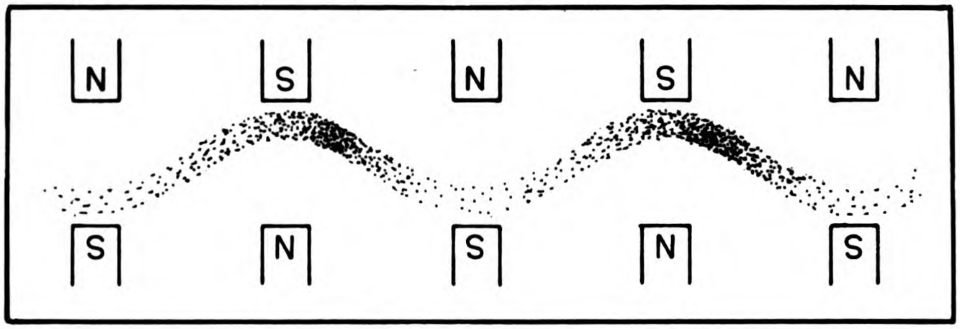
Cavity for 3-millimeter magnetron

It is shown in the theory of relativity that an observer, moving with a velocity approaching that of light with respect to a stationary frame of reference, sees distances marked out along the stationary frame (in the direction of motion) considerably shortened. This strange phenomenon is called Fitzgerald Contraction, and baffled the physicists of the previous generation. But relativity theory has come to stay, and we have become used to it. Now we even make bold to use the phenomenon practically.

Consider an array of magnets producing a magnetic field which alternates in space along the direction z (see diagram below), and a beam of electrons moving with high speed parallel to this direction. Upon entering the field array, they will be laterally deflected and follow a nearly sinusoidal orbit. This is an orbit of the kind we want, with regularly spaced accelerated portions; hence radiation is emitted. What is its wavelength? Let us consider an observer moving with the electrons. He sees the space period of the field distribution shortened by a factor $(1 - \beta^2)^{1/2}$, where β is the ratio of the axial electron velocity to the speed of light. For electrons moving with the high speed which results from acceleration by 3 million volts, the factor $(1 - \beta^2)^{1/2}$ turns out to be 1/7. Thus in the electron frame of reference the wavelength is one-seventh the distance from crest to crest of the magnetic field. And there is yet another effect which plays into our hands.



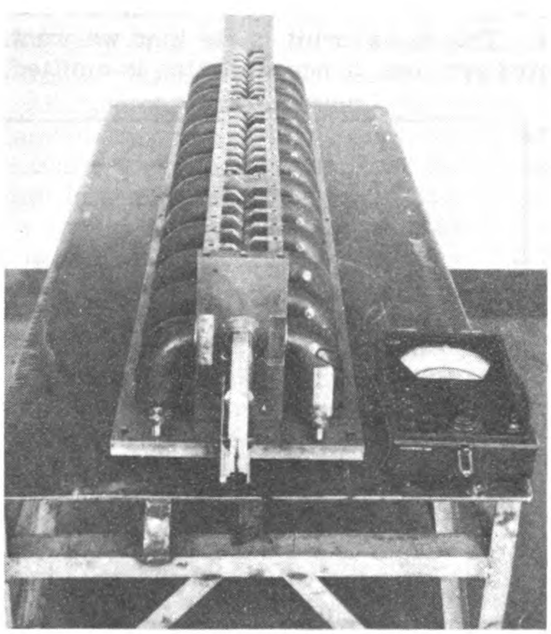
Magnetic field B produced by magnet array (not shown) and electron trajectory



Schematic diagram illustrating electron bunches (dense region) which move along the trajectories shown

In the electron frame of reference the electron is just a stationary oscillator. Now imagine an observer facing the electron. He sees a source of radiation, an oscillating electron (our artificial atom), coming towards him. Now it is well known that the sound made by a moving train increases in pitch when it is heard by a stationary observer facing the train. This phenomenon is called the Doppler Effect.

Similarly, an observer facing our oscillating electron receives radiation of higher "pitch," or shorter wavelength. It can be shown that the wavelength is again shortened by a factor of the order $(1 - \beta^2)^{1/2}$. Altogether, the wavelength received is of the order of 1/49 of the magnet period for a 3-million-volt electron. Thus if we make the period of the magnetic field 49 mm, the wavelength of the radiation will be about 1 millimeter. We have thus achieved our aim. We can generate a short wavelength by means of a much larger magnet structure.

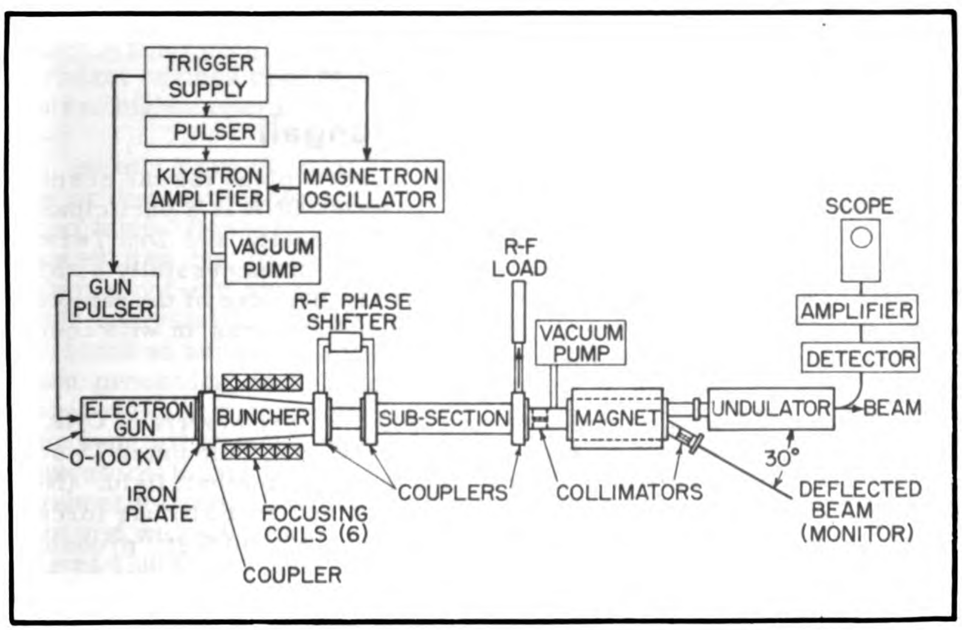


The magnetic undulator

But wait! Is the radiation coherent? If the electrons in the beam are spaced at random distances along the z-direction (see diagram, page 21), the wave trains emitted by individual electrons will start with arbitrary phases and the radiation will be incoherent. But if it proves possible to send the electrons along in bunches, as indicated in the drawing above, and if the bunch length is of the order of half a millimeter, a fair degree of coherence will be achieved. Groups of electrons will then act like one large electron. It turns out that the radiated intensity is a million times higher when the continuous electron flow is broken up and periodically compressed into bunches.

Where can we obtain the large energies necessary for this experiment? Six years ago an electron accelerator imparting an energy of five million volts would have seemed a tall order. But at present, thanks to the pioneering research carried out at Stanford University and elsewhere, a very suitable type of machine is available for the purpose: the linear electron accelerator. It is run on microwave power available from microwave tubes such as magnetrons or klystrons, and lends itself to the incorporation of bunching action. But we are not concerned here with a detailed description of this machine. Suffice it to say that a powerful wave 10 centimeters in wavelength is made to run in synchronism with an electron beam, which is thus subject to continuous axial acceleration by a traveling electric field. During the acceleration period the electrons tend to crowd into positions near the crest of the traveling wave. By proper design, this crowding can lead to a bunch formation suitable for our purpose.

Some preliminary experiments on millimeter wave generation by means of the new principle have been carried out at Stanford University by W. Thon, R. N. Whitehurst, and the author. (Work on the subject was also done at M.I.T. by P. D. Coleman.) A field distribution similar to that illustrated on page 21 was produced by an assembly of permanent magnets with suitable pole pieces. This magnet structure, called a <u>magnetic undulator</u>, is shown partially assembled (with upper set of magnets removed) on page 22. A simplified block diagram of the experimental set-up is shown below. An electron gun is followed by a linear accelerator with bunching action (the "buncher"). For measurement purposes, the electrons pass through



Block diagram of undulator set-up

a magnetic deflector, so that their energy can be measured in terms of the beam deflection produced by a calibrated electromagnet.

This magnet is switched off when the radiation experiment is performed, and the electrons travel on through a waveguide having a cross section of approximately 4 by 8 millimeters, which passes through the pole gaps of the undulator. This waveguide, as well as the accelerator, is evacuated. The guide is bent through an angle of 90 degrees, and the electrons escape through the metal wall of the guide. The waves pass on to a crystal detector, whose output is amplified and fed into a cathode ray oscilloscope. The buncher is supplied with 10-centimeter microwave power from a high-power klystron amplifier, which in turn is driven by a magnetron. This power is applied in pulses lasting one microsecond, repeated 60 times per second. The gun is pulsed in synchronism with the klystron pulses. Encouraging results have been obtained with this equipment. A peak power of the order of watts over a fairly large frequency band at about 1 millimeter wavelength has been observed.

Theory predicts that a beam accelerated by approximately 100 million volts, passing through the same undulator, should produce light. (In this case the waves are not produced coherently, because it is not possible to bunch the electrons within a distance comparable to a light wavelength.) Such a beam is available from the Stanford linear accelerator, and the experiment was performed. It was successful: visible light was indeed obtained. The light was polarized in a direction perpendicular to the magnetic fields of the undulator, as was to be expected. It is interesting to note the enormously wide range of wavelengths which can be obtained from the undulator: from visible light, with wavelengths of the order of 0.0005 millimeter, to millimeter waves 10,000 times as long—all from a single device!

It is hoped to improve the construction of buncher and undulator further. Theoretically, it seems possible to obtain (peak) power outputs of the order of kilowatts in the millimeter range.

Airdrop on Mt. Wrangell

A brief note in our April issue announced plans for the cosmic ray expedition to Mt. Wrangell, Alaska, in which ONR is a participant. Led by Dr. Serge A. Korff of New York University and Dr. Terris Moore of the University of Alaska, the expedition successfully established a camp on the summit on June 20, 1953. Because of the remoteness of the mountain—it is 210 miles south of Fairbanks, in wild country—the camp is being supplied by airdrop.

On June 23, an airdrop, arranged by LT Sidney Morris of ONR's Special Devices Center and flown by the Air Force, pinpointed 25,000 pounds of supplies into an area about the size of a football field. (Net loss—one drum of gasoline!) The camp's 14,000-foot altitude forced the plane to fly at nearly 200 miles an hour at 15,000 feet: probably one of the highest airdrops ever made.

The BOROLITES --

High Temperature Materials by Powder Metallurgy

Paul Schwarzkopf

. . . President of American Electro Metal Corporation, Yonkers, New York, has been active for many years in almost all branches of powder metallurgy. He is the author of Powder Metallurgy (Macmillan, 1947) and (with R. Kieffer) Refractory Hard Metals (Macmillan, 1953).

After the end of the last war, when the metallurgist had a chance to pause for breath and take stock, three factors became evident: (1) There was a definite demand for new high-temperature materials—materials that would withstand greater stresses and corrosive attack, particularly by oxidizing gases, at higher temperatures than the presently used so-called superalloys. (2) Since modifications of known superalloy compositions could not be expected to meet this demand, a different approach was indicated. (3) Powder metallurgy was the logical choice for this new approach.

During the war, the metallurgist had in general been able to meet the requirements of the engineer in applications such as turbo-supercharger blades. At that time, the term "high-temperature materials" was understood to refer to temperatures up to say 1,500 degrees Fahrenheit. However, as soon as such materials were at his disposal, the engineer began to think in terms of 1,800° and 2,000° F; and there is no doubt that, as soon as these are available, he will ask for mechanical strength and oxidation resistance at 2,500° F and higher. The engineer is hard to satisfy. To justify his ever-increasing demands, he points out that further progress in the construction of gas turbines, jet engines, and rocket engines depends to a large extent on the availability of materials for higher operating temperatures.

Up to a limit of about 1,600° F, the so-called superalloys perform more or less satisfactorily, at least as long as the expected lifetime is not too high. However, developments in this field fail to promise advances into the region of markedly higher temperatures. At temperatures not far above 1,500° or 1,600° F the superalloys begin to exhibit recrystallization and grain growth. These phenomena can be understood as atomic mobility, and thus decreased resistance to deformation processes such as creep. Whether or not this argument is of general validity, a chronological review of high-temperature materials of the superalloy class reveals an asymptotic approach to the present temperature limit. Thus, it can be predicted that mere modifications of presently known alloy compositions will result in only minor improvements and will not permit the attainment of service temperatures in the order of 1,800° or 2,000° F.

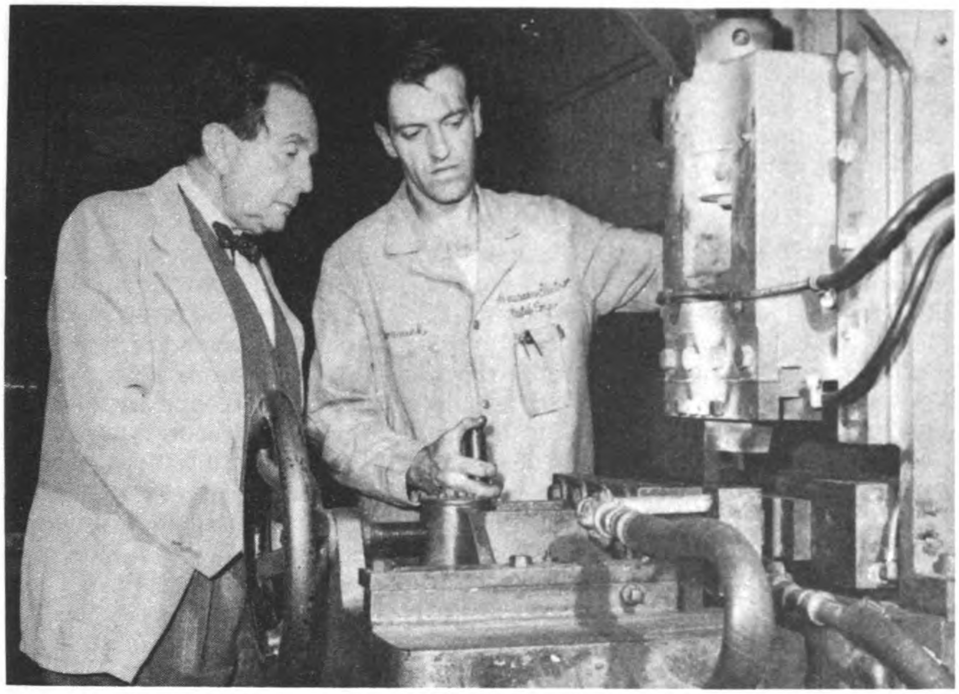
It had thus become evident that development work had to be concentrated on other classes of materials. In addition to metals, ceramics were, and still are, under consideration. High-temperature strength and oxidation resistance of a number of ceramic materials are satisfactory. However, the extremely high brittleness and thermal-shock sensitivity of most available ceramics are prohibitive, and all attempts to eliminate these shortcomings (for example, by adding ductile metals to oxide compositions) have so far failed.

As far as metallic materials were concerned, it was clear that the higher the melting point, the better was the high-temperature strength to be expected. This was obvious since all metals soften at temperatures close to the melting point. Theoretical derivations and consideration of phenomena such as recrystallization were, therefore, not necessary for this conclusion. With the restriction of the potential materials to the highest-melting metals, powder metallurgy became the logical choice of production method, since this technique permits the processing of metals which melt at such high temperatures that they cannot be conveniently melted and cast. The metal is powdered, shaped under pressure, and then heated, without complete fusion, to form a compact mass.

The refractory metals, tungsten and molybdenum, met the mechanical requirements, but were not oxidation resistant at the contemplated service temperatures. Tungsten was of only minor interest since the high specific gravity of this metal is a disadvantage for applications, such as turbine buckets, which involve centrifugal stresses. For molybdenum it was attempted to develop ceramic and other protective coatings. It is too early to say whether those presently available will prove fully satisfactory. In any case, such protection appears possible. It will, however, be difficult to introduce a material whose performance depends on the adherence and imperviousness of a coating. It would definitely be preferable to use a material which itself is oxidation resistant and does not require protective coatings.

The second class of high-melting standard products of powder metallurgy which were considered for high-temperature applications were the so-called hard metals—the carbides, borides, nitrides, and silicides of the transition metals of the fourth to sixth groups of the periodic system. Cemented carbide compositions as used for tools and wear-resistant parts have—like the refractory metals—the required strength but fail to exhibit sufficient oxidation resistance at high temperatures. Again, these standard compositions could be used only when provided with protective coatings. Modified compositions, in which tungsten carbide (the base constituent of standard cemented carbides) is eliminated and titanium carbide becomes the main constituent, have markedly improved oxidation resistance. This improvement is achieved at the expense of the strength, but for service up to about 1,800° F, both strength and oxidation resistance appear satisfactory for most intended applications.

For temperatures higher than 1,800° or perhaps 1,900° F, however, no carbide-based material can be used when both strength and oxidation resistance are requirements. The realization of this limitation did not, however, mean that all hard metals had to be excluded for potential use at markedly higher temperatures.



An early stage of powder metallurgy is pressing the metal powder. Here, Dr. Schwarzkopf and an assistant are watching the operation of the press.

At this point, a theoretical consideration enters the picture. The carbides are peculiar substances; they have the composition of inorganic chemical compounds but they look and behave like metals. Their characteristic properties are interpreted as being determined by their crystal and electronic structure; that is, by the relative arrangement of their component atoms in the solid state and by the nature of the forces holding these atoms together. Their electrical and thermal conductivity performance clearly indicates metallic bonding. This means that the forces holding the atoms together are of the same character as those acting in metals. The strength and hardness and other mechanical properties are closely connected with this bonding character.

This metallic nature of bonding is common to all hard metals: to the corresponding borides, nitrides, and silicides, and consequently it could be expected that these compounds would exhibit similarly favorable mechanical properties. As mentioned before, the mechanical performance of carbides at high temperatures appears promising and their usefulness is limited mainly by the lack of oxidation resistance. Since similar high temperature strength values could be expected from hard metals other than carbides, it appeared worthwhile to look among these compounds for some which, in addition to mechanical strength, would also exhibit the required oxidation resistance at high temperatures.

Since the chemical stability of the nitrides appeared inferior to that of borides and silicides, a study of these latter two groups seemed most promising.

About seven years ago—under Office of Naval Research sponsorship—we started a systematic investigation of the borides of the transition elements. Some of these borides had been known since the time of Moissan, French chemist and Nobel prize winner who lived during the last half of the nineteenth century. Others had been reported more recently but quite a few we had to synthesize ourselves to cover the entire field. We had to establish the phase diagrams of the metal-boron systems in order to recognize those from which the best performance as high-temperature material could be expected.

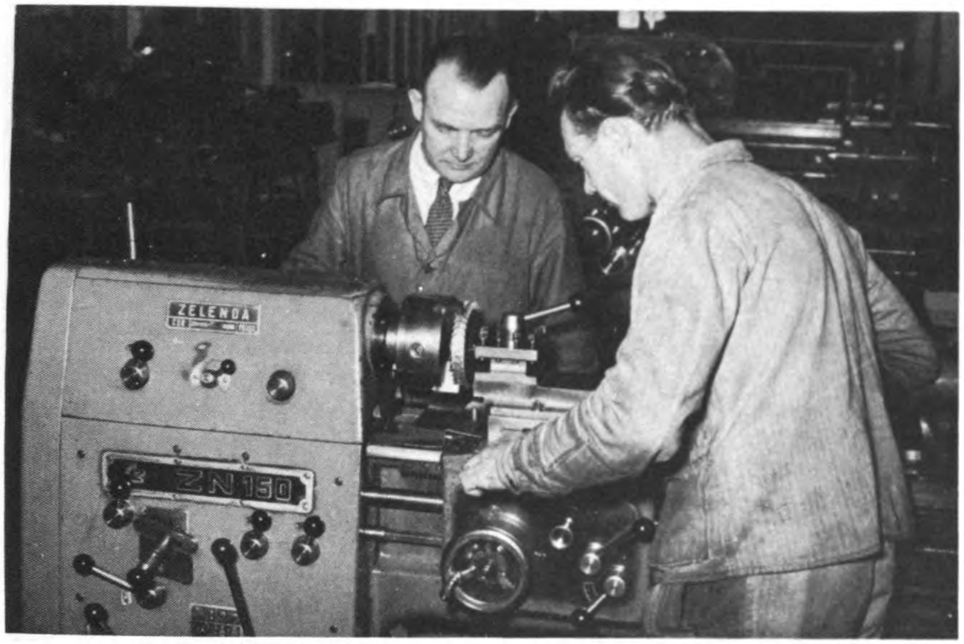
We had to learn how to handle these new materials. That means we had to learn how to fabricate solid bodies and parts from boride powders. In this, our experience in the carbide field was of help. In general, standard procedures of powder metallurgy such as pressing and sintering, hot pressing, or extrusion are applicable to the processing of borides. In some respects, however, our experience in the carbide field was far from helpful, leading to lengthy and costly detours. We tried, for instance, to produce bodies by cementing the boride powders with cobalt and nickel—a standard procedure in the industry of cemented carbides. Our first results were promising but we soon reached a temperature limit. Today we know that this limitation was due to the formation of unstable borides of cobalt and nickel. We had to establish stability limits of these borides in order to recognize that the temperature limit with our nickel- and cobalt-bound borides represented an unsurmountable barrier.

We had to find and found other binders which did not lead to the formation of unstable compounds at service temperatures, and we succeeded in developing a series of boride materials—the so-called BOROLITES—which exhibit, at high temperatures, remarkable strength, thermal shock resistance, and chemical stability, including oxidation resistance.

A drawback is some extent of brittleness at room temperature. Because of the metallic nature of the borides this brittleness is, however, considerably less pronounced than in the case of ceramics. But there is no doubt that, at least in some applications, the higher brittleness of hard metals in comparison with presently used superalloys will necessitate design modifications.

When the engineer is complaining that the operating temperatures permitted with the materials supplied by the metallurgist are not high enough for his purposes, it should be permissible that the metallurgist in turn formulate his complaints. So far the engineer has not been able to give a definite answer to the question: what extent of room temperature brittleness is permissible in applications such as turbine buckets, for instance. We are able to modify the BOROLITE products and increase the room temperature ductility, but this improvement is at the expense of high-temperature strength. In other words, the higher the required room temperature ductility, the lower will be the creep resistance and stress rupture strength. Since the engineer could not tell us how much ductility he needs, our aim was to develop a series of materials rather than a single one, so that we can tell the engineer the maximum high temperature strength we can expect for each particular room temperature ductility limit.

In gas turbines and the like, an increase of operating temperatures involves a complete redesign of the entire engine. Since all



Here a metal wheel is being machined. This operation takes place after presintering, when the hard metal has a consistency similar to that of graphite.

laboratory tests give only incomplete information, the final test will have to be performed in an experimental turbine. The scarcity of such testing facilities has induced several metallurgical research organizations to construct their own experimental gas turbines. A special feature of the experimental turbine of my organization in testing our titanium carbide-base high temperature materials was that wheel and buckets were produced from one piece. This was possible since the material was readily machinable in the presintered state. The use of the same method in testing our new BOROLITE materials is contemplated.

One of the BOROLITE materials has recently found important peace-time applications. Most of these are based on the high chemical stability of the material in contact with molten metals such as aluminum, copper, brass, magnesium, and tin. Among these recent applications are nozzles for powder production by spraying molten metals, pump components for continuous die casting, electrodes for fused salt electrolysis, vibrating rods for producing an ultrasonic field in molten metals, and thermocouple protection tubes. Since the material has become available only recently, it is expected that many more peace-time applications will be found.

The foregoing was mainly concerned with the development of the BOROLITE materials. The picture would not be complete without mentioning other development work now in progress in the laboratories of the powder metallurgist. I refer in particular to two classes of materials. One is the silicides which, like the carbides and borides, are of metallic nature, and thus belong to the hard metal class. Silicide research has, among other things, indicated that molybdenum disilicide can be used in resistor heating elements which will perform satisfactorily in oxidizing furnace atmospheres at temperatures higher than

Checking dimensions of the wheel

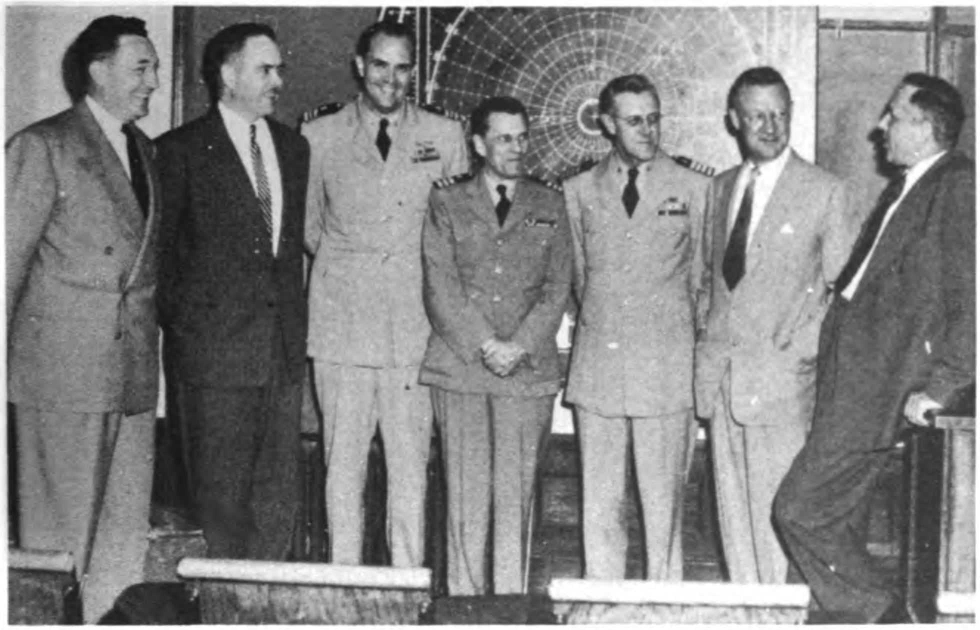
3,000°F. Other silicides may very well prove useful in applications requiring, in addition to oxidation resistance, high mechanical strength at elevated temperatures.

The other class I want to mention is that of intermetallic compounds. We have obtained highly promising results with materials produced from high-melting compounds between two or more metals of definite composition. These intermetallic compounds cannot be classified as hard metals. Most of these compounds had been previously known but were considered as useless on account of their inherent brittleness. In fact, in some instances the formation of these compounds had been carefully avoided in the production of alloys by casting methods. At least in some instances we were able to produce useful and ductile materials of particularly high corrosion resistance at elevated temperatures by synthesizing the pure intermetallic compound and subsequently processing this compound by standard methods of powder metallurgy.

Altogether, I dare say that the recent successes of the powder metallurgist justify an optimistic outlook in the field of high temperature materials. At present, the engineer is not prepared to design gas turbines or jet engines for operating temperatures higher than about 1,800°F. The materials offered by the powder metallurgist for this temperature limit appear highly promising. It appears to me permissible to expect that the powder metallurgist will be ready with materials for service at 2,000°F and above before the designer of engines will be ready to advance to this range of temperature.

On the Naval Research Reserve

Captain Grimes Addresses Company 1-7

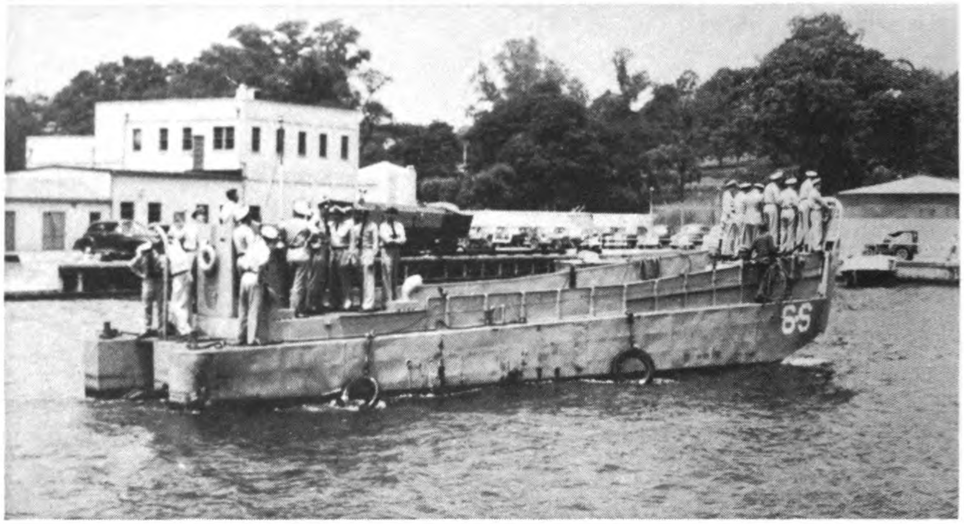


Members of Company 1-7 (Dartmouth College, Hanover, N. H.) considered themselves highly honored in having Captain C. G. Grimes, Deputy and Assistant Chief for Naval Research, as speaker at their meeting on 26 May. In the picture above are, left to right: LCDR M. E. Heffernan, Program Officer; CDR F. J. Boyle, Executive Officer; LCDR R. K. Buchanan, ONR Washington; CDR H. Wray Rohrman, ONR Boston; CAPT Grimes; CAPT T. H. Tonseth, Professor of Naval Science and Tactics, Dartmouth College; CDR C. Z. Dimitroff, Commanding Officer of VNRRC 1-7.

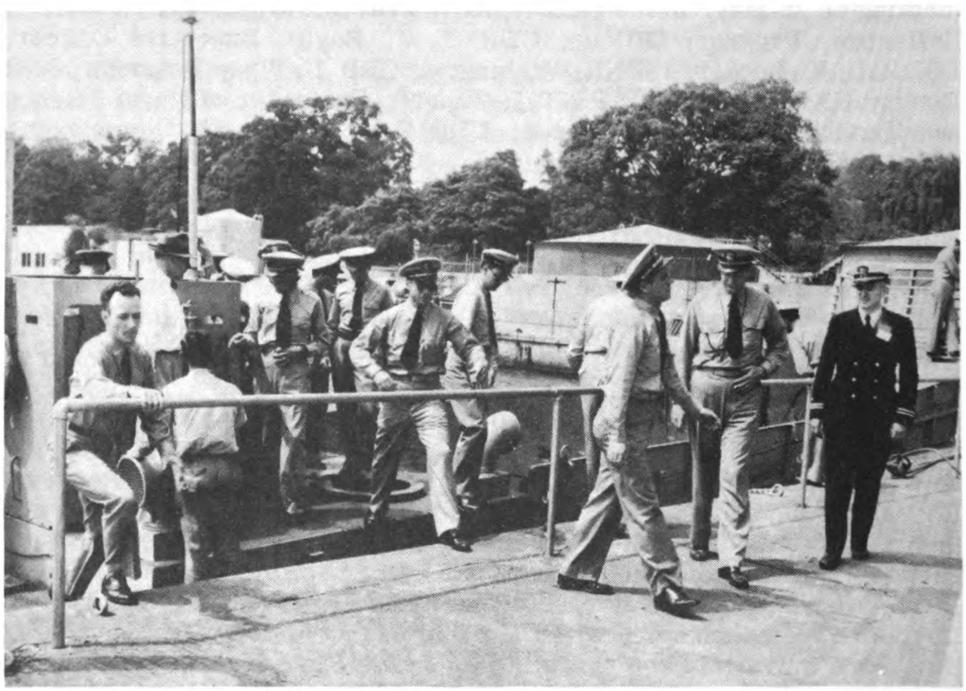
LT Tiedemann National Historian for Reserve Officers Association

LT Albert W. Tiedemann, Jr., USNR, Commanding Officer of NRRC 5-4 (Baltimore, Md.), was recently honored by being selected as national Historian for the Reserve Officers Association. LT Tiedemann was attending Loyola College in Baltimore, Md. when he received orders to active duty in 1943. Assigned to the Notre Dame Midshipman School, he was commissioned the next year as an Ensign in the Naval Reserve. He served on the USS LCI (L) 444 in the Southwest Pacific Area and then returned to the U.S. as Communications Officer at the Naval Barracks in Washington. He has been affiliated with the Reserve Officers Association since his release to inactive duty in 1946. Going back to Loyola, LT Tiedemann received his B.S. degree in 1947 and his M.S. at New York University two years later. Now a candidate for the Ph.D. at Georgetown University, he is instructor of chemistry at Mount Saint Agnes College in Baltimore.

Reservists from ONR Washington Seminar Visit Engineering Experiment Station at Annapolis



Members of ONR Washington Seminar (14 to 27 June) aboard the LCM-6-S at the U.S. Naval Engineering Experiment Station, Annapolis, Md. The craft is being used for tests of a new type chain drive designed to permit repair on propellers and rudders without hauling out or utilizing divers.



Disembarking from the LCM-6-S

New Company in Logan, Utah

Another new company, Naval Reserve Research Company 12-7, recently activated at Utah State Agricultural College, Logan, Utah, has joined the swelling ranks of the Research Reservists. Charter members are shown above with CDR Joe Graham, Research Program Officer for the Twelfth Naval District. On CDR Graham's right is LT Dean K. Furriman, Commanding Officer of the new Company.

LCDR Faulkner, New Program Officer for Southeastern Area

LCDR Charles D. Faulkner, USNR, reported this month as Program Officer for the Southeastern Area. He relieves LCDR Walter P. Warren, who has returned to civilian life at his own request. LCDR Faulkner's Naval experience dates back to 1942. His education includes a B.A. degree in 1928, and later an M.A. from Stetson University, Deland, Florida, postgraduate study at George Washington University and at Cumberland University. Before World War II he was Principal of the Bartow, Fla. High School. He served his first tour of duty with the Naval Reserve from June 1952 to August 1945. During this time he was Assistant to the Head of the Ordnance Department in the Naval Midshipman School, New York City, for two years. He also served as Assistant Gunnery Officer on board a destroyer escort and as head of the Ordnance Department at the Naval Pre-Midshipman School at Princeton.

Before leaving for active duty he set up a training program for veterans under the Florida School Department. He was Training Officer and Psychologist with the Naval Advanced Air Training Command at Corpus Christi, Texas. His most recent civilian occupation was Principal of the Mulberry, Florida Schools. LCDR Faulkner comes to ONR Washington from duty as Inspector-Instructor for Naval Reserve in the Chattanooga, Tenn. area since November 1950.

Naval Research Company 9-8 Announces Organization Billets

Pictured above are reserve officers attending a meeting of NRRC 9-8 (St. Louis, Missouri) on 29 May. In the front row, left to right are: LCDR A. B. Phillips; LCDR J. B. Baltzer; CDR J. H. Carter, Commanding Officer; LCDR W. L. Robison, Research Program Officer, Chicago Branch of ONR; CDR R. N. Varney, LT W. P. Armstrong. In the back row: LT I. N. Mensh, ENS R. N. Pallardy, LT J. L. Loy, LT I. L. Shechmeister, LT J. E. Taylor, ENS F. L. Rupel, LTJG H. J. Jobse, LT R. V. Bovbjerg, LCDR L. C. Widdoes, 2nd LT (USAFR) Charles Kilo.

The following billets and duties have been announced as of 1 July: Commanding Officer, CDR John H. Carter; Executive Officer, CDR Robert N. Varney; Training Officer, LT Ivan N. Mensh; Assistant Training Officer, LCDR John B. Baltzer; Assistant Training Officer, LT I. L. Shechmeister; Training Aids Officer, LCDR Lawrence C. Widdoes; Administrative Officer, LT Willard P. Armstrong; Security Officer, LT Leon U. Jameton; Public Information Officer, LCDR Harrison A. Hoffmann; Special Events Officer, LCDR David S. Gilmore; Policy Board: CDR Robert N. Varney, LT J. L. Loy, LCDR Alroy B. Phillips, LT J. E. Taylor, and LT R. V. Bovbjerg; Information Officers: Promotion & Retirement, ENS R. N. Pallardy; Correspondence Courses, LTJG J. N. Goulias; Training Duty, LTJG E. G. Jaworski.

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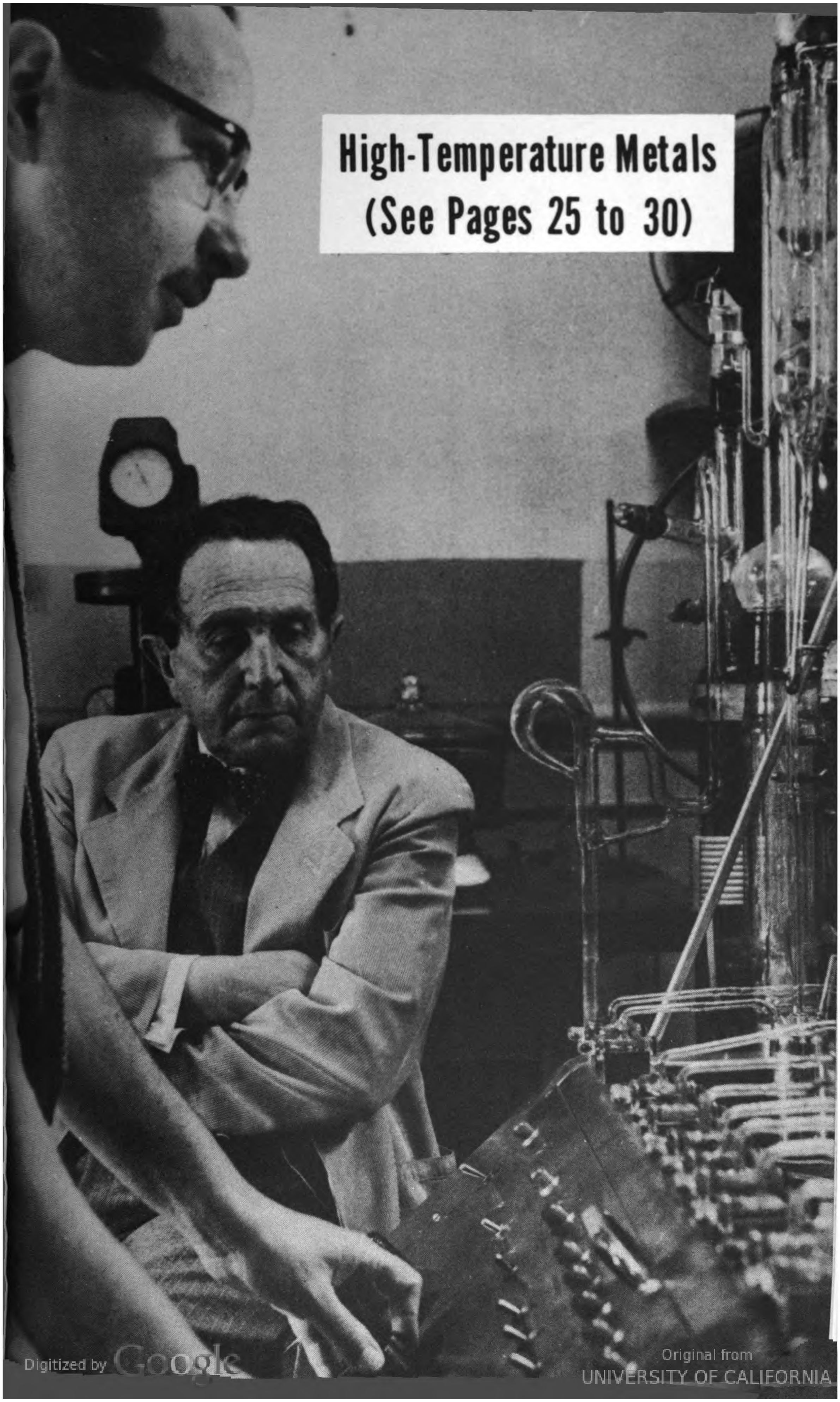
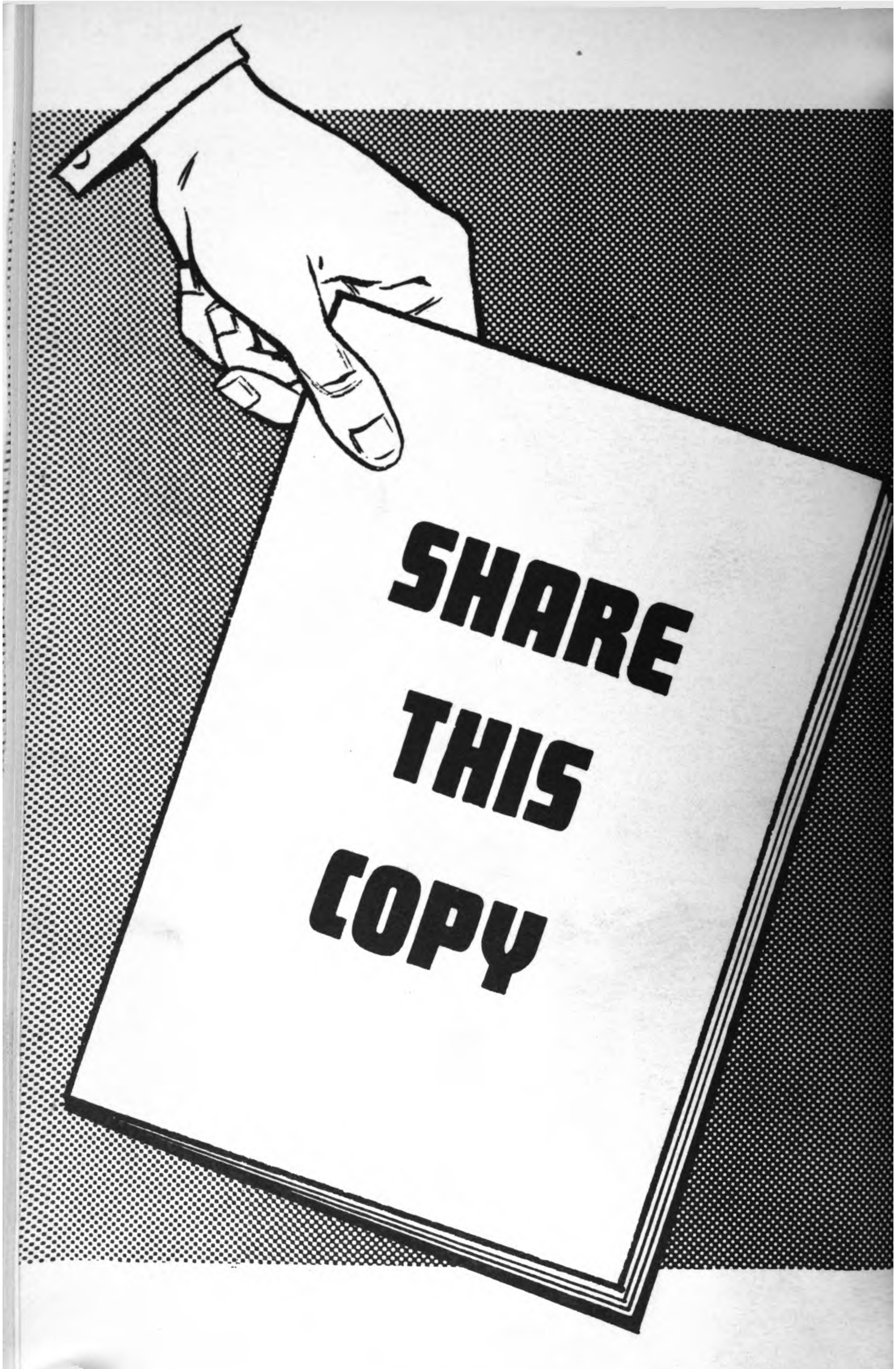


High-Temperature Metals
(See Pages 25 to 30)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