JANUARY 1950

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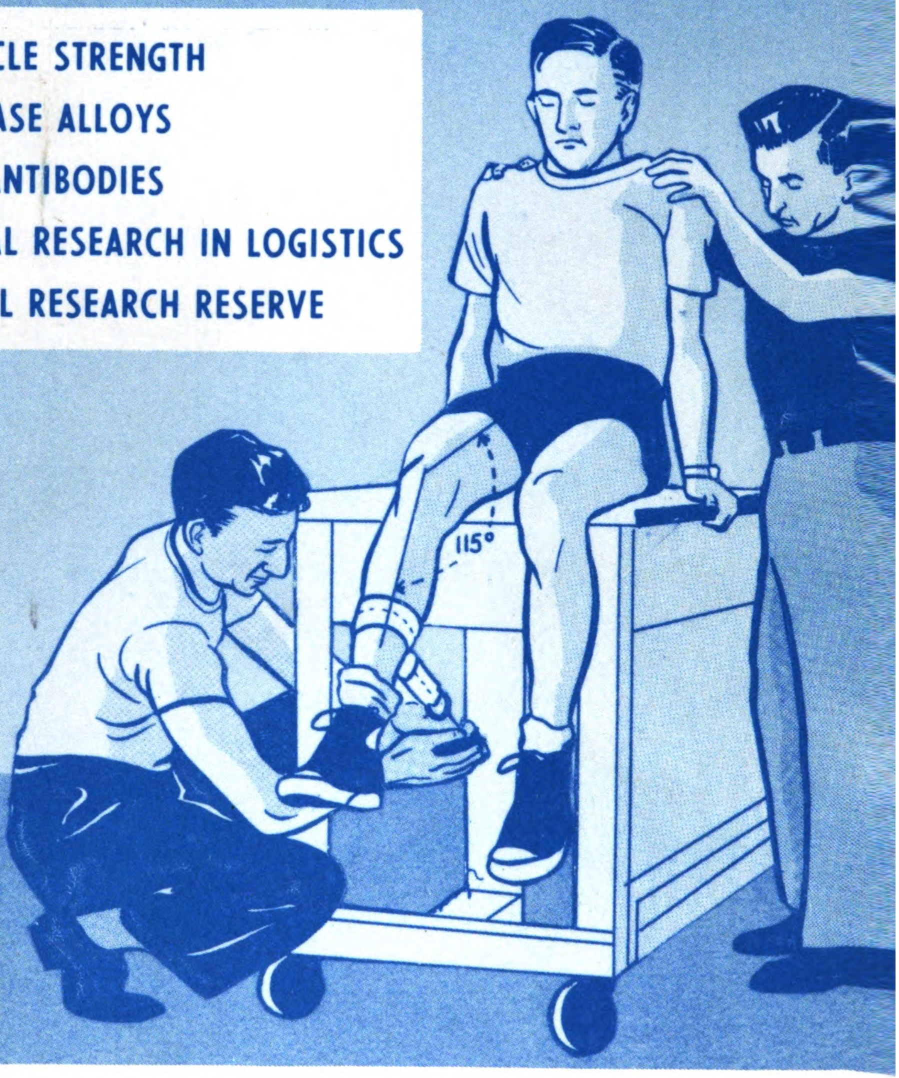
RESEARCH REVIEWS

- TESTING MUSCLE STRENGTH
- CHROMIUM-BASE ALLOYS
- BLOOD AND ANTIBODIES
- MATHEMATICAL RESEARCH IN LOGISTICS
- ON THE NAVAL RESEARCH RESERVE



OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

NAVEXOS P-510

COVER: The position for a knee extension test---one of the various tests applied in studying the strength of muscles---is illustrated here. The subject is shown in a sitting position with arms extended to the rear and hands grasping the sides of the table; a pulling strap around the knee and ankle joints has a cable attached below and behind the subject. This is one of the positions selected on the basis of kinesiological analysis for TESTING MUSCLE STRENGTH. See story on page 1.

Approved by Bureau of the Budget, 13 April 1948.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research

Contents

JANUARY 1950

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH

Editorial Notes

The Nobel Prize for Chemistry for 1949 was awarded to William Francis Giauque, professor of thermodynamics at the University of California, for his studies of the behavior of matter at temperatures close to absolute zero. Dr. Giauque has perfected a method for reducing the temperature of small amounts of matter to a few thousandths of a degree above absolute zero. At this low temperature, under the laws of thermodynamics, unruly matter should be at complete rest. However, Dr. Giauque has made startling discoveries of disorder in matter at temperatures close to absolute zero. The world's foremost expert on cold, Dr. Giauque is at present conducting low-temperature research at the University of California under ONR contract.

Nobel prize winners who are also ONR contractors now total seven.

Irving Langmuir, associate director of the Research Laboratory of the General Electric Co., Schenectady, N. Y., was awarded the Nobel Prize for Chemistry in 1932 for his work in surface chemistry. Dr. Langmuir engaged in the development of gas filled tungsten lamps, electron discharge apparatus, condensation high vacuum pump, and atomic hydrogen welding. In 1917 and 1918 he worked on devices for submarine detection at the Naval Experiment Station, Nahant, Mass. At the present time, Dr. Langmuir is working on Project Cirrus, an ONR project devoted to studies in cloud physics.

G. H. Whipple, dean and professor of pathology at the School of Medicine and Dentistry of the University of Rochester, was the recipient of a Nobel joint award in medicine and physiology in 1934. He is presently conducting, under ONR contract, a study of plasma proteins with labeled amino acids.

H. C. Urey, professor of chemistry at the University of Chicago, received the 1934 Nobel Prize for Chemistry. Dr. Urey specialized in the structure of atoms and molecules, thermodynamic properties of gases, and separation of isotopes. He is the discoverer of Deuterium, the hydrogen isotope of atomic weight two, and conducted research for the production of heavy water and U235 for the atomic bomb. Dr. Urey is at present engaged in the investigation, under ONR contract, of natural abundance of stable isotopes.

Carl D. Anderson, California Institute of Technology, received the Nobel Prize for Physics in 1936. Dr. Anderson's research includes work on X-ray photoelectrons, on gamma-rays and cosmic-rays, and discovery of the positron in 1932. He is at present conducting cloud chamber cosmic ray studies for ONR.

Enrico Fermi, professor of physics at the University of Chicago, received the 1938 award in physics. An outstanding figure in the field of atomic physics, he is working on the 100-Mev Betatron Installation project of ONR.

Isador Isaac Rabi, received the physics award in 1944. He was a staff member and associate director of the Radiation Laboratory at the Massachusetts Institute of Technology and is now conducting molecular-beam investigations for ONR at Columbia University.

ONR is both proud and gratified to have men of such recognition and authority as pioneers of new frontiers in research for the Navy and the Nation.

Testing Muscle Strength

by
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Springfield College

This study was begun as a research project in physical reconditioning in the Army Air Forces Convalescent Hospital program during the war, and continued at the Physical Education Research Laboratory, Springfield College, under the auspices of the Office of Naval Research. In the course of this work apparatus and objective techniques were devised for measuring the strength of muscles activating movements of the joints(1) . These tests are eventually intended for application to muscles involved in orthopedic and neuromuscular disabilities. Initially, 28 tests were proposed, based on certain movements of the wrist, elbow, shoulder, hip, knee, and ankle joints. Coefficients of objectivity between 0.92 and 0.97 were obtained for the various tests by the test-retest method with different testers and with non-disabled college men as subjects. A trial of the tests on patients with orthopedic disabilities at the U. S. Naval Hospital, Chelsea, Mass., revealed that, in general, the results coincided well with medical opinion of patient status.

Subsequently, tests measuring the strength of other joint movements of the body, including the finger, neck, and spine, and additional movements of the wrist and ankle, have been devised. A total of 37 tests are now available involving nearly all the muscle groups of the body.

In this type of objective testing of strength, a specially adapted and calibrated aircraft tensiometer (Figure 1) is utilized to record the amount of tension the subject can apply to a cable appropriately placed for specified movements of the joints. A homemade pulling apparatus is used. The subject is tested on a plinth.

A consideration of the application of strength by specific muscle groups is indicative of the type of studies carried on during the past year. The ability to study such muscle action is in itself of considerable basic interest to physical educators, physical therapists, kinesiologists, and doctors of physical medicine. In studying the strength of muscle groups, two main approaches were employed as follows: (1) A consideration of the most effective body position for the application of strength by the muscles controlling the joint movements; and (2) a determination of the amount of muscle strength which can be applied by

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H. Harrison Clarke, professor of physical education and Director of Graduate Studies at Springfield College, Springfield, Mass., received his B.S. degree in physical education from that college in 1925. He received his M.S. and Ed.D. degrees from Syracuse University. Professor Clarke was Director of Physical Education for the Chautauqua, N. Y. public schools from 1925 to 1930. From 1930 to 1945, he was chairman of Teacher Training and Physical Education at Syracuse University. Professor Clarke has written numerous articles and research reports for professional journals and is the author of The Application of Measurement to Health and Physical Education, published in 1945 by Prentice-Hall, Inc.

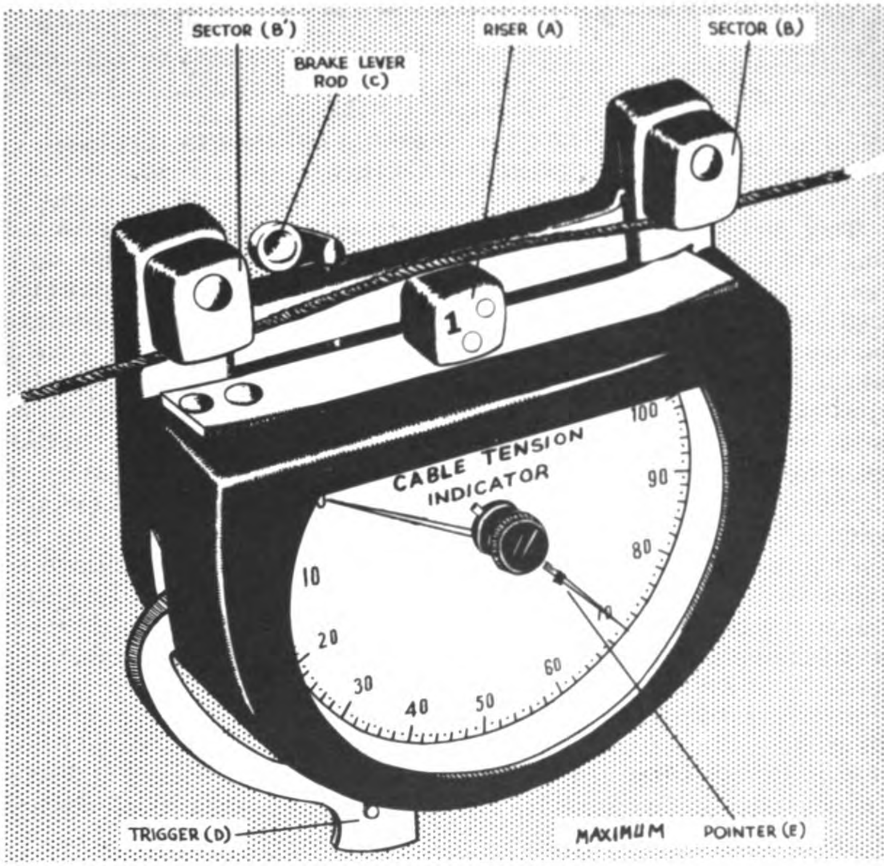

Figure 1. A specially adapted and calibrated aircraft tensiometer for the objective testing of strength.

the muscles throughout the range of movement of the joints. In this report, the muscular action of the following three selected joints are described: knee extension, hip flexion, and hip extension. These tests were selected as they illustrate three different types of curves when their strengths are plotted throughout the range of motion of the joints.

Alternate body positions were selected on the basis of kinesiological analysis made by consultants on physical medicine at the Mayo Clinic. Sixty-four non-disabled male college students served as subjects. In each case, the means of the tensions in both positions were computed. The differences between the means were tested for significance in accordance with the null hypothesis. On this basis, values for t of 1.67 and 2.37 denoted significance at the 0.05 and 0.01 levels of confidence respectively for small samples. These values for t were chosen because, in this study, significance was measured from zero, or no difference, in a positive direction only.

In studying the muscle strength exerted throughout the range of motion of each joint, a number of test positions were selected approximately 20 degrees apart. The fatigue element from repeated maximal exertions of the same muscles, while present, was reduced by space testing and was equalized by systematically changing the sequence of tests for the various subjects. The subjects again were 64 non-disabled male students.

In the studies which follow, 0 degrees is a position away from the median line of the body; 180 degrees parallels and is in line with the median line. Thus, for example, at 0 degrees in abduction of the shoulder, the arm is over the head; and at 180 degrees, it is close to the body.

Knee Extension. The original position for the knee-extension test was as follows: the subject was in a sitting position, with legs hanging free and arms folded on the chest. The knee of the leg being tested was in 135 degrees of extension. The pulling strap was placed around the leg midway between the knee and ankle joints, the cable being attached below and behind the subject. The tester stabilized the subject by preventing the lifting of the hips by bracing, and preventing inward and outward rotation of the hip joint.

The alternate position was also a sitting position but the subject was leaning backward, with arms extended to the rear, and hands grasping the sides of the table (Cover).

The results of the amount of strength applied in the two positions by the 64 students were as follows: the mean for the original form of the test was 112.94 pounds (51.3 kgs.); for the revised form, 147.94 pounds (67.1 kgs.). The average for the revised form was 35.00 pounds (15.0 kgs.) greater. The t was 4.86, indicating a statistically significant difference.

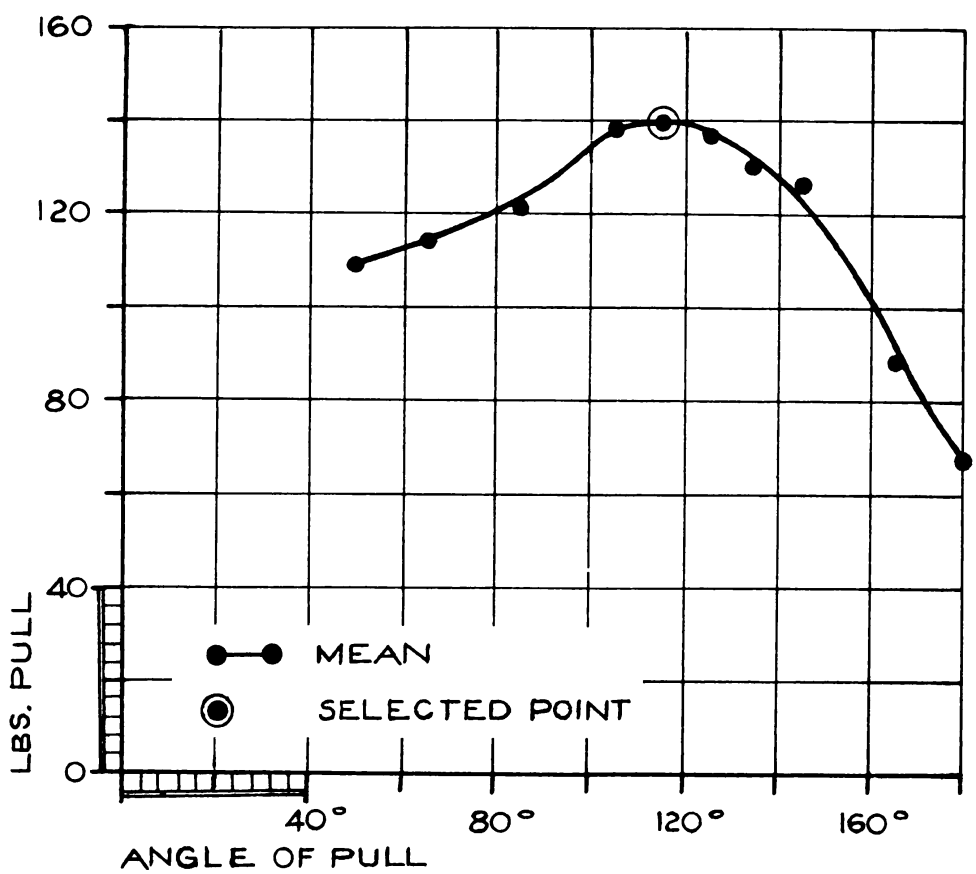

Figure 2. Knee extension strength curve.

In determining the strength curve for the knee extension movement, the subject was placed in the position found most effective as described above, i.e., in a sitting position, leaning backward with arms extended to the rear, hands grasping sides of the table, and legs hanging free. As shown in Figure 2, nine positions were tested in this movement. It will be noted that the curve on the graph started at a low point at one end, rose to a maximal height in the middle, and descended to a low point at the other end. The positions of the knee joint are as follows: 180 degrees with the knee fully extended; 40 degrees with the knee fully flexed.

The greatest strength of the knee extensors was found to be in the mid-parts of the joint movement, from 105 to 125 degrees. The low point was at full extension, 180 degrees. At the opposite point, full flexion, the muscles were on greater stretch, but, although they pulled well, they appeared to be at a mechanical disadvantage.

Hip Flexion. The original hip-flexion test was made with the subject lying supine with the leg not being tested at rest on the table and

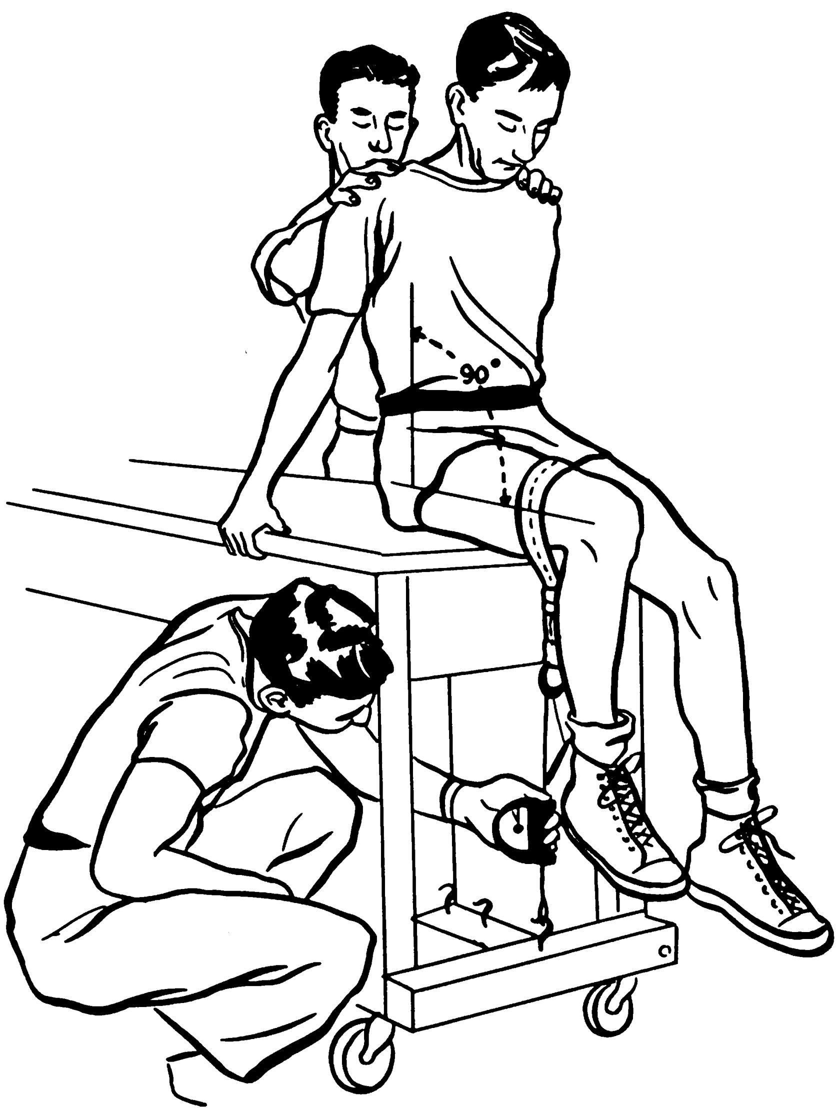

Figure 3. Hip Flexion.

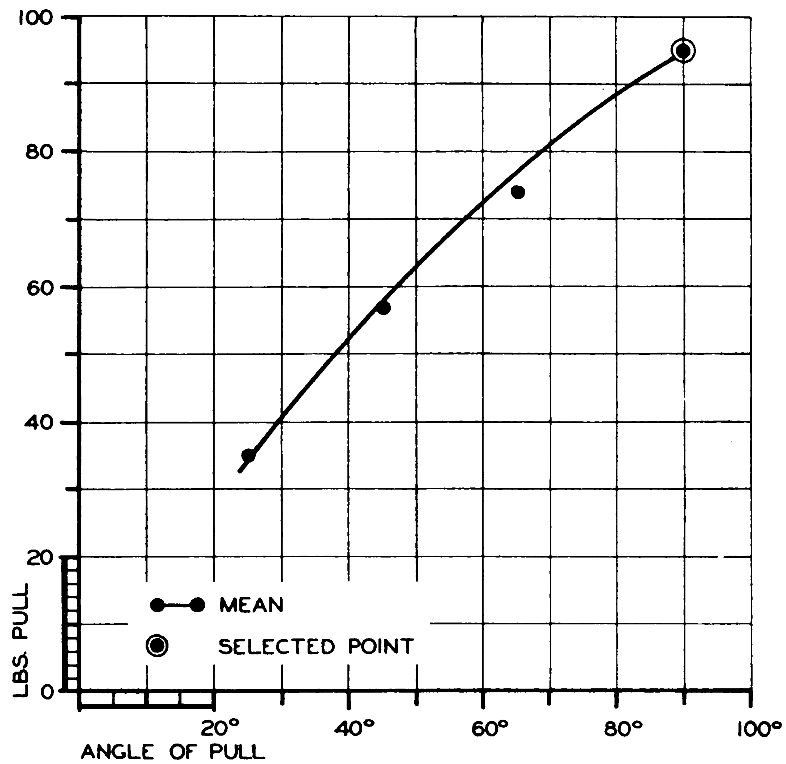

Figure 4. Hip flexion strength curve.

arms folded on chest. Hip of the thigh being tested was in 120 degrees of flexion; knee was flexed with the angle not specified. The pulling strap was fastened around the lower third of the thigh, with cable attached at subject's feet. By bracing, the tester prevented lifting of the leg not being tested, and also raising of the hip of the leg being tested.

The alternate position for this movement was as follows: the subject was sitting and leaning backward, with legs hanging free, arms extended to the rear and hands grasping sides of the table (Figure 3). The hip on the side of the thigh being tested was flexed to 90 degrees and the knee was in 90 degrees flexion. The strap was attached around the lower third of the thigh, with the cable hooked below the subject's legs. The tester prevented lifting of the hips by bracing with the hand.

The results of this testing were as follows: the mean for the original form of the test was 64.81 pounds (29.4 kgs.); for the revised form, 115.00 pounds (52.2 kgs.). The average for the revised form was 50.19 pounds (22.8 kgs.) greater, an improvement of 77 percent. The $\underline{t}$ was 15.78.

Apparently the increased power demonstrated in the new position was due to the angle at which the iliopsoas muscle functioned. It is probable that the muscle applies its greatest rotary force when power is being exerted at a right angle to the longitudinal axis of the femur.

In studying the strength curve for hip flexion, the alternate form of the test was used. It should be noted that the test was restricted to testing the strength exerted from 25 degrees, close to the body, to 90 degrees, at a right angle sitting position. As shown in Figure 4, the

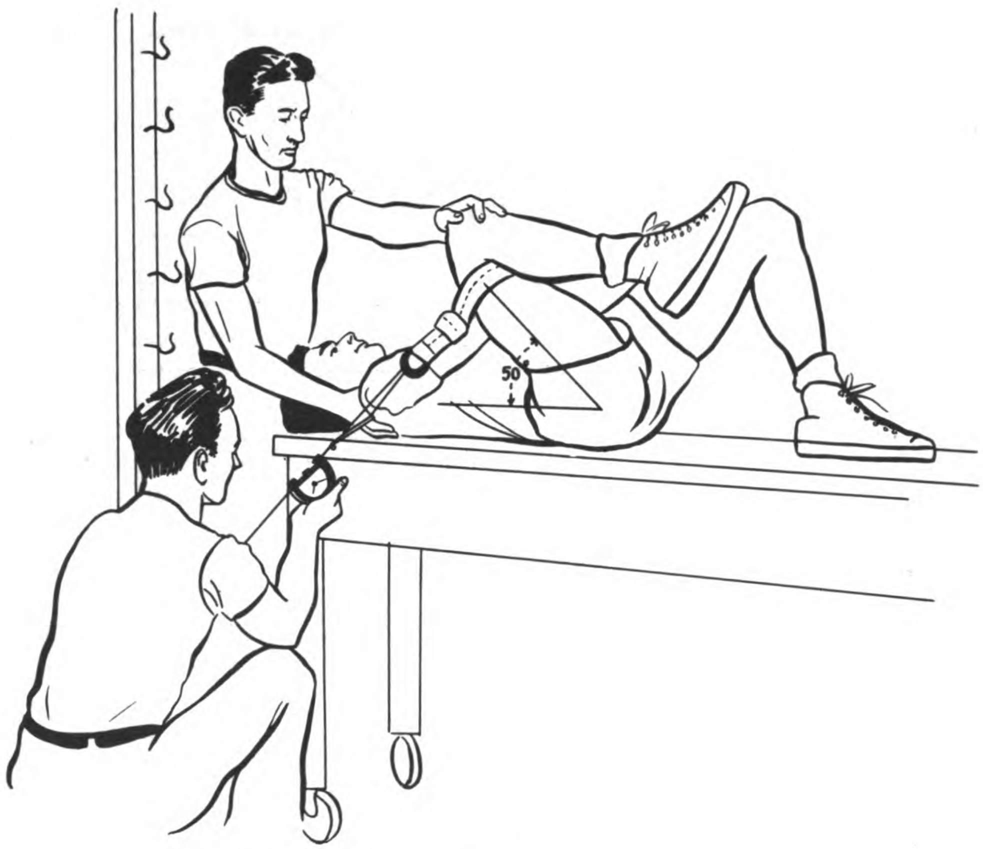

Figure 5. Hip extension.

subjects could only pull an average of 35 pounds (15.9 kgs.) with the thigh fully flexed, while recording an average of 90 pounds (40.8 kgs.) (plus the weight of the legs) when the flexors of the thigh were on greater stretch. The pitch of the curve representing strength exerted is very sharp, being a straight-line rise. It is believed that still greater strength would have been possible in this joint movement if the position of the body could have been so arranged as to allow a greater extension of the hip when testing.

Hip Extension. In the original hip-extension test the patient was on a table in sitting position, with legs hanging free, and arms folded on chest. The thigh was flexed at the hip joint to 70 degrees, and adducted at the hip joint to 180 degrees. The strap was fastened around the lower third of the thigh, with the cable attached to an overhead hook. The tester prevented lifting of the leg not being tested and raising of the hip of the leg being tested by bracing.

In the alternate position for this movement the subject was lying supine, with arms folded on chest (Figure 5). The thigh was flexed at the hip joint to 90 degrees, and adducted to 180 degrees. The strap was fastened around the lower third of the thigh, with the cable attached at the subject's head. The tester prevented lifting of the hips by bracing. An assistant also braced against the shoulder to prevent slipping on the table.

The results of this testing were as follows: the mean for the original form of the test was 73.25 pounds (33.3 kgs.); for the revised form, 130.75 pounds (59.4 kgs.). The average for the revised form was 57.5 pounds (26.1 kgs.) greater, an improvement of 78 percent. The $\underline{t}$ was 8.26.

In the original testing position, the quadriceps are in a shortened position, and the hamstring muscles offer a counter tension. In the revised position, the quadriceps are more nearly at their full length and the tension of the hamstring muscles is not as great.

In studying the strength curve for hip extension, the alternate position which proved most effective in the application of muscle power, as described above, was used. As shown in Figure 6, greatest strength was again exerted when the hip was fully flexed, with the muscles tested being at their full length. It will be noted that a plateau existed at the end of the test, which was partly due to the increased effect of the weight of the leg on test scores as it straightens out. The power of the extensors of the hip was great indeed, the average for the subjects tested being 180 pounds (84.4 kgs.)[2]

In studying the muscle curves presented (Figures 2, 4, and 6), it will be seen that three types of graphs were found, as follows: (1) as-

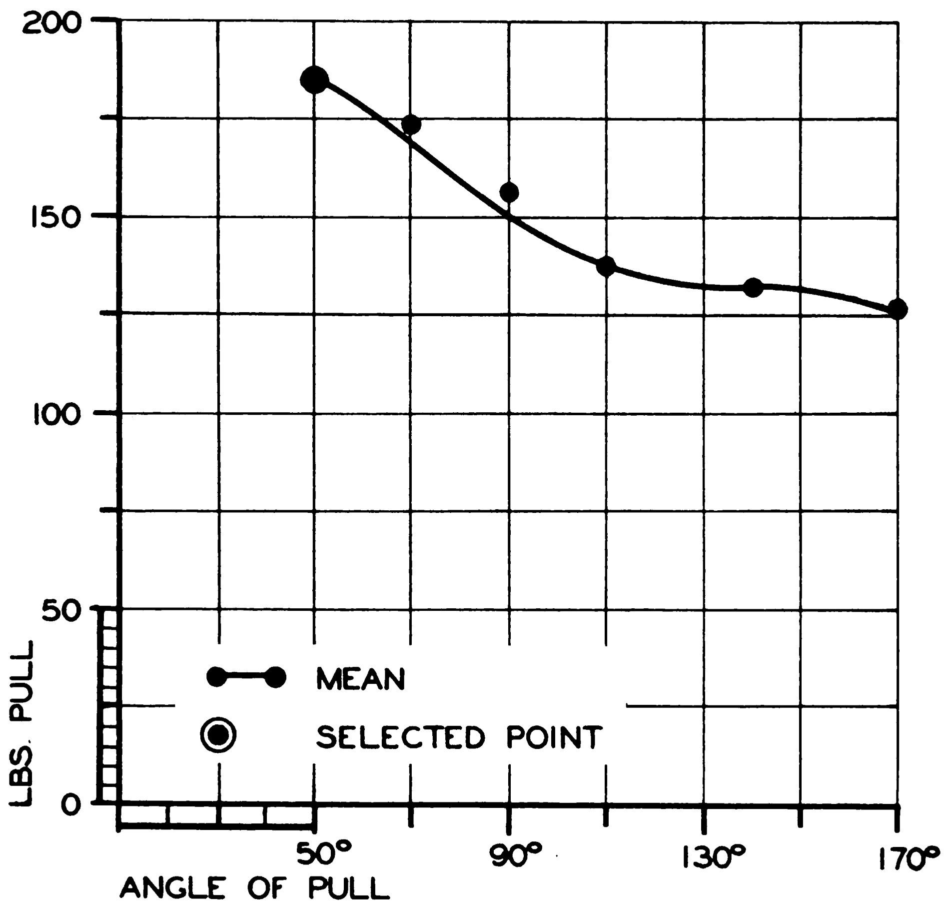

Figure 6. Hip extension strength curve.

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cending-descending curves, with greatest strength exhibited in the center of the range; (2) ascending curves, that is, increase in strength on motion of joints from angles of 0 to 180 degrees; and (3) descending curves. These three graphs are typical of the strength curves as found for other joint movements. For example: ascending-descending curves were found in elbow flexion, shoulder adduction, shoulder extension, and knee extension; ascending curves, in hip flexion, knee flexion, shoulder forward flexion, and shoulder abduction; and descending curves, in hip extension and elbow extension. There were, however, individual variations of pitch and plateaus within these classifications.

These studies of the amount of strength that can be applied by different joint movements in alternate body positions and for the strength applied by the muscles throughout the range of movement of these joints provide objective evidence for the statement that, other things being equal, a muscle exerts its greatest power when it functions at its greatest tension; that the angle at which the muscle pulls is of importance but probably not as important as the tension; that there probably is an optimal position in which each muscle functions the best; that this position may be one in which the tension is optimal (not necessarily maximal), and in which the angle of pull provides for the greatest rotary forces.

Stabilizing force, or the force exerted parallel to the long axis of the bone, is not measured in this study. However, in the knee extension test studied, this force may be considerable at full extension of the knee and in addition to the rotary component measured.

Studies such as those described above deal with only a few of the problems which may be investigated in relation to muscle functions from mechanical and kinesiological standpoints. The testing procedures, which were originally intended to measure the strength of affected muscles involved in orthopedic disabilities, however, need not be limited to this use. Such testing procedures may, for example, be applied to problems in human engineering. It should be possible to determine the amount of strength required to perform specific industrial or military operations demanding strong physical exertion, so that appropriate personnel may be selected for such jobs. And, as a result of such studies, machines may be so designed and operations be so ordered as to assure ease of operation when strength is required.

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Acknowledgments are made to Theodore L. Bailey, research laboratory supervisor, and the following graduate students in physical education at Springfield College, who assisted in the collection of test data and in the statistical computations necessary for the studies reported and others completed in orthopedic strength testing under ONR contract: James L. DePasquale, Dean U. Harrell, Paul B. Kirkland, Donald K. Mathews, Henry J. Pilote, Jr., Edwin J. Richardson, Arthur R. Troisi, and Nicholas F. Troisi, Jr.

(1)H. Harrison Clarke, "Objective Strength Tests of Affected Muscle Groups in Orthopedic Disabilities," Research Quarterly, American Association for Health, Physical Education, and Recreation, Vol. 10, No. 2, May 1948, p. 118.

(2)Direct comparison of pounds of pull for the various tests reported is not possible, due to the unequal effect of gravity in the test positions.

Chromium-Base Alloys

by
Walther L. Havekotte
Battelle Memorial Institute

This is the last in a series of four articles prepared by members of the staff of Battelle Memorial Institute who are conducting research for ONR on heat-resisting materials.

Prior to World War II, the metals that were used at high temperatures under stress were iron-, nickel-, and cobalt-base materials. However, when the United States entered the war in December, 1941, better alloys were needed to withstand greater loads at higher temperatures—for example, for turbine blades rotating in an oxidizing atmosphere at temperatures up to 1600°F (870°C).

As a result of research at the Climax Molybdenum Co. during the war and more recently at Battelle Memorial Institute, chromium-base alloys containing iron and molybdenum were developed. These alloys show better strength at 1600°F than do the best commercially available alloys.

Prior to this work on chromium-iron-molybdenum alloys, the strongest high-temperature alloys were cobalt-base materials. However, at that time cobalt was not plentiful, since most of it was imported and very little of it was stock-piled. Furthermore, the chances of improving the iron, nickel, or cobalt alloys to keep up with the development of gas turbines were not too good. Thus, one of the problems facing the metallurgist was how to make a better heat-resistant alloy without using cobalt.

In March, 1942, the War Metallurgy Committee of the National Defense Research Committee asked the Climax Molybdenum Co. to look into this problem. The ensuing investigation ran for about three and a half years.

These investigators surveyed the Periodic Table in search of a promising base metal for a new alloy system. Some of the metals were not plentiful. Others melted at temperatures just above 1600°F (870°C). Because of these two shortcomings, about 75 percent of the metals were eliminated. The field was narrowed further on the basis of melting point and high-temperature oxidation resistance, and finally chromium was selected as the base material to be studied intensively.

Vacuum-melting and casting equipment and procedures for preparing chromium-base alloys were developed. The alloys were melted

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in vacuum to reduce contamination by oxygen and nitrogen. A preliminary screening of the alloys was made using the hot-hardness test. Those alloys which yielded high hot-hardness values were tested in creep rupture. (The chief method of evaluating high-temperature strength today is by creep-rupture testing. This test consists of subjecting a material to a constant load at a constant temperature, and observing the rate and amount of elongation and the time to rupture.)

The chromium-rich portions of 13 binary and nine ternary systems of chromium were examined. Most of the ternary alloys contained iron, since this improves the ductility of chromium and, in preparing the alloys, permits using chromium in its cheapest form, ferrochromium. Also, iron is similar to chromium and does not affect its melting point greatly.

Chromium-iron-base alloys containing molybdenum, tungsten, or tantalum gave the best combination of strength and ductility at 1600°F and of shock resistance at room temperature. The molybdenum-bearing alloys had better mechanical properties and were lighter and cheaper than the others. The availability of molybdenum in this country was another factor favoring the further development of these alloys.

Of the chromium-iron-molybdenum alloys, those with 60 percent chromium, 15 to 25 percent iron, and 25 to 15 percent molybdenum showed the most useful strength and ductility at 1600°F (870°C). The 60Cr-15Fe-25Mo type alloy was the strongest. The 60Cr-25Fe-15Mo type alloy was the most ductile. For compositions between these two, the properties varied continuously, with the high-temperature strength decreasing and the ductility increasing as the Mo:Fe ratio decreased.

At this stage of development, in September, 1945, the Office of Naval Research, Navy Department, sponsored a project at Battelle Memorial Institute on Alloys and Ceramics for High-Temperature Service. One phase of this project was a further study of chromium-base alloys. This was aimed at obtaining chromium-base alloys with better combinations of strength and ductility than those shown by the Climax alloys. To carry out this program, the effects of improving the melting and casting techniques, modifying the chemical composition slightly, and using various heat treatments were investigated.

In preparing the chromium-base alloys, preliminary heats were made by reducing the metal oxides with finely divided aluminum (thermite process). This method of production was not successful. The Climax vacuum-melting and casting method was then adopted, and an apparatus similar to the Climax unit was designed and built (Figure 1).

The melting equipment consists of a beryllia crucible of three and one quarter pound capacity held in the center of a 26-inch-long Vycor tube by insulating material. An induction coil is located outside the Vycor tube and is connected to an Ajax Northrup 35-KW spark-gap converter. To aid in melting the charge and in distributing the heat uniformly, the crucible is wrapped with a sheet of molybdenum. This sheet, heated by the induced current, heats the crucible and melts the charge. The 60Cr-15Fe-25Mo type alloy melts at about 3050°F and is tapped at 3250 to 3400°F, usually into a zircon refractory mold.

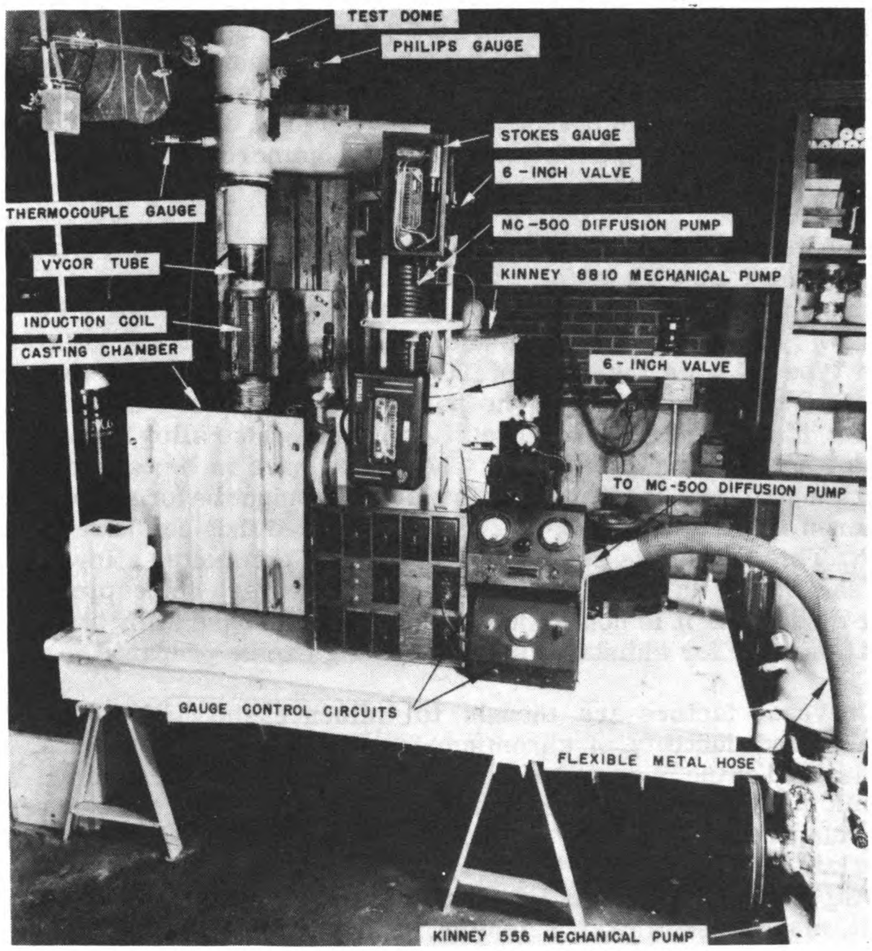

Figure 1. Vacuum-melting and casting apparatus used in preparing chromium-base alloys.

At tapping, the pressure in the casting chamber is less than 10 microns of mercury (approximately 0.001 percent of atmospheric pressure). A heat is tapped by exciting a solenoid which withdraws a zirconia-ball stopper plug from a hole in the bottom of the crucible. The molten metal drops out of the crucible under the force of gravity and flows into the mold.

A refractory combination hot top and funnel is used on the top of a refractory mold to assist in pouring and feeding the casting. The funnels and molds are made by ramming refractory material (usually zircon) into the desired shapes. These are heated slowly to 2300°F to develop the ceramic bond, and then cooled to room temperature. Mold design largely eliminated microporosity, pinhole porosity, and columnar grains from the castings.

After the alloy is poured, the casting is sectioned and machined or ground to size for testing. The 60Cr-25Fe-15Mo type alloy can be machined, but the 25 percent molybdenum type alloy must be ground. The 25 percent molybdenum alloy is quite susceptible to cracks and, therefore, must be ground carefully.

To investigate a method of producing chromium-base alloys commercially, several heats were melted under a slag in an induction furnace (at atmospheric pressure) and poured into molds without any protective atmosphere. These alloys were not as strong as those prepared by vacuum melting and casting, but nevertheless, the results were encouraging; air melting showed promise as a commercial means of making chromium-base alloys.

Heats were also air-melted in connection with a cursory evaluation of investment materials for casting chromium-base alloys. (The investment-casting process is used by dentists in preparing gold-inlay fillings.) Attempts are being made to investment-cast the 60Cr-15Fe-25Mo type alloy in the form of TG-190 turbine blades for test in an experimental gas turbine. The purpose of this study is to obtain a general idea of the performance of chromium-base alloy blades under simulated operating conditions. The blades have to be cast to the appropriate size and shape since this material cannot be forged or readily machined. The surfaces of the blades prepared thus far have been too rough. This roughness seems to be a result of the molten alloy reacting with the binder in the investment mold. However, some progress is being made, and it is hoped that soon chromium-base alloy blades that are acceptable for simulated service testing can be prepared.

Several factors are thought to influence the high-temperature strength and ductility of chromium-base alloys. These include: materials used in the charge (for example, electrolytic chromium vs. fused chromium), deoxidizers, time that the alloy is held molten before tapping, furnace pressure at tapping, metal temperature at tapping, mold materials, Mo:Fe ratio of the alloy, Cr content of the alloy, addition of alloying elements, such as titanium, zirconium, tungsten, columbium, cobalt, manganese, nickel, selenium, and vanadium, and heat treatment, particularly solution treatment with and without aging. All of these factors are being studied, but the research is by no means complete.

The addition of two percent titanium to the 60Cr-15Fe-25Mo type alloy and changes in the vacuum-melting and casting techniques were responsible for increasing the creep-rupture strength of this alloy over the values obtained at Climax. Several bars of the 58Cr-15Fe-25Mo-2Ti type alloy withstood stresses of 40,000 psi at 1600°F for more than 500 hours before breaking. A heat-treated bar showed the outstanding time-to-rupture of 1764 hours under these test conditions.

The creep-rupture strength of this alloy is much higher than those of the best cobalt-base materials. At 1600°F, the strongest chromium-base alloy had a creep-rupture life that was 15 times as great as that of one of the best cobalt-base alloys (X-40) while supporting twice the load. However, the high-temperature ductility of the chromium-base material is poorer than that of the cobalt-base alloys. At room temperature, the chromium-base alloys are so brittle that they must be handled with care to prevent breaking. Several test bars broke while being placed in the creep-rupture test units. Because of this brittleness and consequent inconsistent creep-rupture test data, it is believed that the testing to date of these alloys has not given a fair appraisal of all of the effects of the above-mentioned factors on high-temperature strength and ductility. However, there are enough data to indicate that the Mo:Fe ratio influences ductility; the 60Cr-25Fe-15Mo type alloy

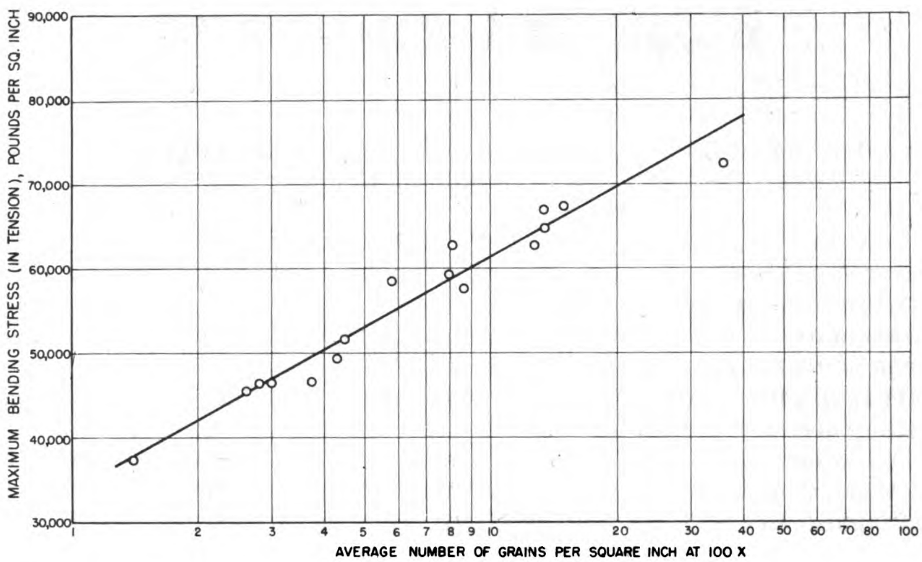

Figure 2. Effect of grain size on maximum bending stress (in tension) at room temperature for 16 chromium-base alloy heats.

shows more high-temperature ductility than does the 60Cr-15Fe-25Mo type alloy.

A material that is as brittle as the chromium-base alloys would be hard to handle in production operations. Also, the low ductility at high temperatures would decrease the usefulness of this high-strength material. Consequently, a study is now being made on how to improve the room-temperature ductility or shock resistance of chromium-base alloys. The results of this study will probably suggest how to improve high-temperature ductility.

Bend testing at room temperature was adopted as a means of evaluating shock resistance. The effects of several factors on shock resistance, as indicated by maximum deflection and/or maximum bending stress (in tension), are being measured. These variables include chemical composition (especially carbon, chromium, iron, oxygen, and nitrogen contents), pouring temperature, mold preheat temperature, deoxidizers, grain size, and heat treatment. This study is still in the early stages, but bend-test data already obtained show that, the finer the grain size, the higher is the shock resistance (i.e., the maximum bending stress). This correlation is illustrated in Figure 2.

Fractured bend-test bars, particularly the areas adjacent to the fracture, have been examined under the microscope. Several bars showed slip lines in the centers of the grains. The presence of these lines indicates that the material was plastically deformed, at least to a small extent. Usually, the amount of deformation that occurs in a material before fracture is a reflection of the shock resistance of the alloy. Thus, the slip lines found in chromium-base alloys show that this material has some ductility, and there appears to be some hope of increasing it.

In the event of another emergency, the demand for gas turbines, and consequently for blades, will be even greater than any previous demand. The best high-temperature alloys that can be developed will be needed to satisfy future requirements. Therefore, work is continuing on the improvement of the mechanical properties of chromium-base alloys.

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Blood and Antibodies

by
Lawrence E. Young, M. D. and Richard M. Christian, M. D.
University of Rochester School of Medicine and Dentistry

It has been known since 1900 that there are four major types of human blood and that patients may have serious reactions if transfused with blood of a type different from their own. In recent years, finer differences in human blood have been discovered, particularly differences with respect to the so-called "Rh factor." Persons whose red cells lack this factor may suffer reactions if transfused with red blood cells containing the Rh factor. Moreover, an Rh-negative woman (that is, one whose cells lack this factor) married to an Rh-positive man may have an Rh-positive baby affected with anemia and jaundice due to the incompatibility between her blood and the baby's blood.

Extensive studies on blood groups in dogs have recently been made in the Department of Medicine of the University of Rochester School of Medicine and Dentistry. Four different red cell factors have thus far been identified in dog cells and one of these, which might be called the "Do factor," is similar in some respects to the Rh factor in human blood. Do-negative dogs may have serious reactions if repeatedly transfused with Do-positive blood. Do-negative bitches mated with Do-positive sires may have Do-positive puppies affected with anemia and jaundice similar to the condition seen in human babies. An important difference, however, is that the Do-antibodies responsible for destruction of the pup's red blood cells reach the pup's blood stream via the dam's breast milk while human Rh antibodies reach the baby's blood stream by passage across the placenta. The maternal and fetal circulations are separated by fewer layers of cells in the human species than in dogs, and this may account for the fact that maternal antibodies traverse the human placenta but not the dog placenta. Newborn dogs, like certain other newborn animals, obtain maternal antibodies solely from the mother's breast milk and they are capable of absorbing antibodies from the digestive tract only during the first day of life.

Dr. Lawrence E. Young received his M.D. from the University of Rochester, Rochester, N. Y. in 1939. He served his internship at Strong Memorial Hospital, Rochester, N. Y., finishing in 1940. Dr. Young held a residency in internal medicine at Strong until 1941 and then served a residency in Rochester Municipal Hospital until 1943. He was an assistant in Bacteriology at Johns Hopkins University in 1942. At the time he entered the Navy in 1942, he was teaching medicine at the University of Rochester. He is presently the chief investigator of ONR's project at the University of Rochester on Immunological Studies of Red Cells.

Dr. Richard M. Christian received his B. A. and M. D. degrees from Vanderbilt University and served his internship at Vanderbilt University Hospital. Dr. Christian was a Fellow in Pathology at the same hospital in 1946-47 and an assistant resident in medicine in 1947-48. He is at present a Fellow in Medicine at the University of Rochester School of Medicine and Dentistry.

Antibodies reacting with red blood cells of various species are thought to be similar to those reacting with bacteria and other infectious agents used in vaccinating or immunizing people for the purpose of preventing infectious diseases. The portion of the bacterium or of the red blood cell membrane which reacts with a specific antibody is called a hapten. The antibodies are molecules of gamma globulin or protein produced in certain cells of the body in such a way they react with or "fix" the haptens much as a key fits a lock. That is, antibodies produced in the body by an attack of typhoid fever or by vaccination with typhoid bacilli will react with typhoid organisms but not with streptococci and vice versa.

When red blood cells are mixed with blood serum containing antibodies capable of attaching themselves specifically to one of the many different haptens on the cells, the red corpuscles may be clumped—that is, agglutinated or joined together. Some antibodies are capable of sensitizing red cells in such a way that the cells are lysed or destroyed by the action of complement which is a heat-labile component of normal blood plasma. Before blood can be safely transfused it is necessary to cross match a sample of the recipient's blood serum or plasma (the fluid part of blood) with a sample of the donor's red corpuscles to determine if agglutination or hemolysis will take place in the test tube. It is also desirable to test the recipient's red cells with the donor's serum. If agglutination or hemolysis occurs <u>in vitro</u> in the cross-match a similar reaction might occur <u>in vivo</u> and cause a serious "hemolytic transfusion reaction" in the recipient. Donors selected for transfusion are those whose cells and serum do not react with the recipients' serum and cells in the cross-matching.

Since 1944 a number of newly developed laboratory tests have demonstrated that some antibodies can become attached to human red blood cells without causing either agglutination or hemolysis <u>in vitro</u>. There are strong indications, however, that these so-called "incomplete" antibodies are even more important than "complete" antibodies in producing (1) hemolytic transfusion reactions, (2) anemia and jaundice in newborn babies (erythroblostosis fetalis) and (3) anemia and jaundice due to rapid destruction of red cells in older children and adults (so-called acquired hemolytic anemia associated with auto-antibodies).

One of the most sensitive techniques for detection of the presence of these antibodies on red blood cells is the "developing" or Coombs test. This test is carried out by mixing the antibody-coated cells with serum from a rabbit that has been immunized by injections of human gamma globulin. The anti-globulin rabbit serum agglutinates the cells because the antibody attached to the cells is a globulin. The development of agglutination in this indirect manner has been likened to the development of a photographic film. The Coombs test has great diagnostic value when carried out with red cells from a newborn baby or from an older individual whose cells are thought to be undergoing rapid destruction as a result of the action of an antibody.

Highly diagrammatic sketches of the possible relationships between red cells and complete and incomplete antibodies are shown in Figure 1. Agglutinins which are thought to be bivalent or multivalent antibodies may be pictured as attaching themselves to haptens on red cells and thus bringing about agglutination somewhat as shown in the diagram.

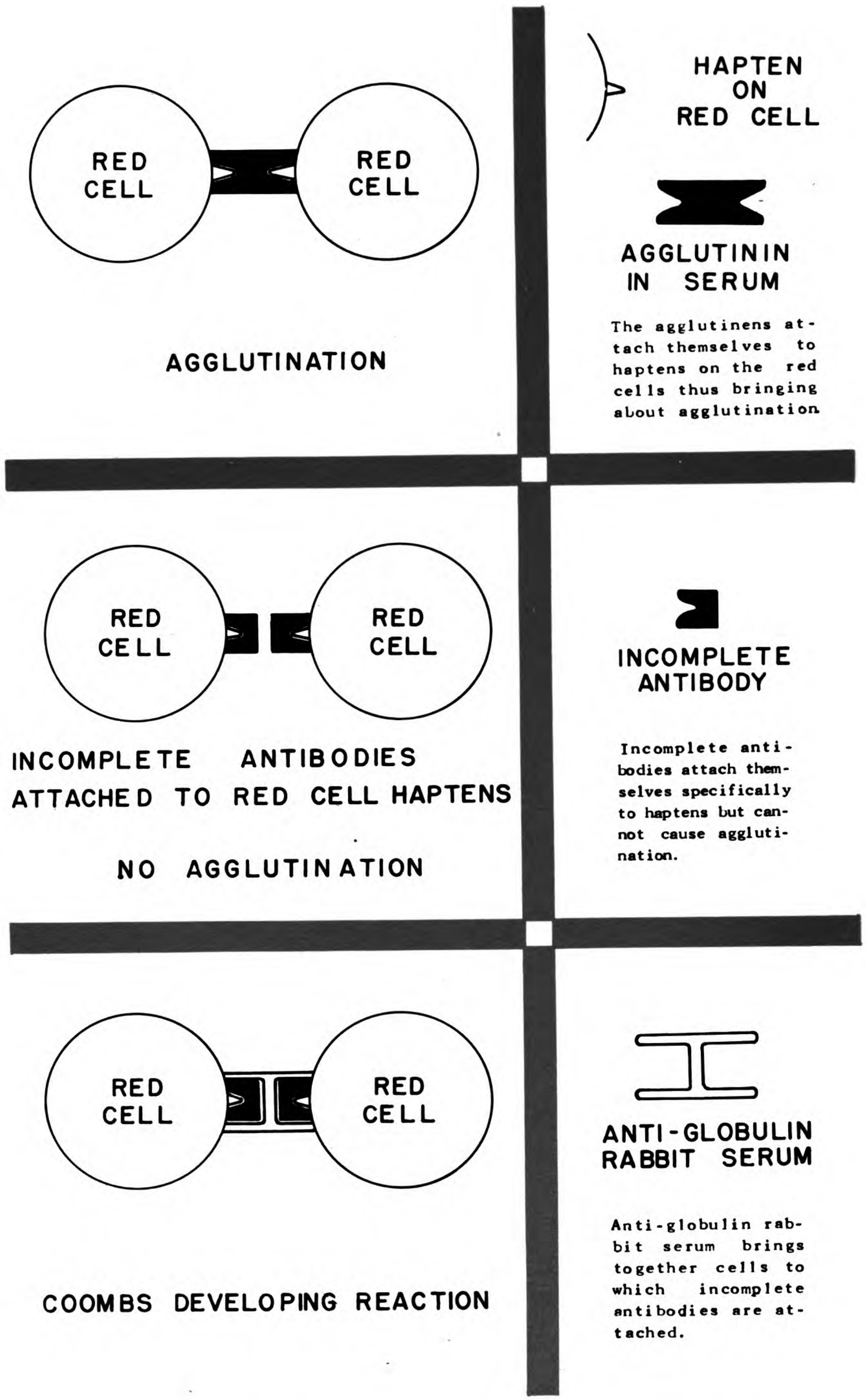

Figure 1. The possible relationships between red cells and complete and incomplete antibodies. The hapten is indicated in the above illustration by the white nodes attached to the red cell.

There are actually many haptens on each cell and the reaction between these factors and agglutinins in the serum is three-dimensional. The illustration is greatly simplified. Incomplete antibodies may be regarded as univalent and capable of attaching themselves specifically to haptens but incapable of causing agglutination. Cells to which such antibodies are attached, however, may be brought together by molecules of rabbit antibody which are specific for human gamma globulin (Figure 1). It should be stressed that the exact nature of these reactions is not understood and that the sketches are based largely on imagination.

It is of interest that dog antibodies can react with dog red cells in a variety of ways just as human antibodies react with human red cells in various ways. Three of the canine antibodies thus far studied appear to be simple agglutinins and are presumably bivalent or multivalent. Do-antibodies, on the other hand, are capable of reacting with Do-positive cells in a number of ways. They may produce either agglutination or hemolysis, but the attachment of some Do-antibodies to some dog cells can be detected only by carrying out the Coombs test with serum from rabbits immunized against dog globulin.

Experiments in progress are designed to reveal the mechanisms by which the red cells of dogs are destroyed by antibodies of various types. Controlled observations on dogs should lead to a clearer understanding of hemolytic phenomena encountered in human beings, especially hemolytic transfusion reactions and hemolytic disease of the newborn. Studies on relationships between dog red cells and incomplete antibodies may also throw light on certain problems pertaining to cancer, leukemia, and other malignant diseases. These diseases in human beings are sometimes complicated by rapid destruction of red cells and it has recently been shown by Coombs tests that incomplete antibodies are attached to the red cells. The origin and exact significance of such "auto"-antibodies are a complete mystery.

* * * * *

Mathematical Research in Logistics

by
C. B. Tompkins
George Washington University

The following lecture was given to the Staff of the Logistics Department of the U. S. Naval War College, Newport, R. I., on September 20, 1949. It is reprinted here with permission of Dr. Tompkins and the U. S. Naval War College.

I am, of course, flattered to have been asked to talk here today. But I am also greatly disturbed, for I shall have to describe the goals of a research project. This is dangerous for two reasons: first, if we knew how the researches were going to turn out (that is, if we could really specify the goals) then the project would not be a research project at all but a straightforward production project; secondly, in order to explain the spirit of a research we frequently find it expedient to mix fairly glibly the goals that we feel fairly confident of attaining within a year or so with hazy ones which may be similar to those which may be attained within a century or so. However, the modern large research problems, which must be attacked by groups rather than individuals, require some sort of announcement of goals. With this understanding, then, I shall present what I consider to be a set of plausible goals for mathematical research in logistics, but these goals in no way constitute more than an implicit specification of the research.

I have the task of explaining what is in the minds of those of us who are directing toward logistics problems an analysis largely mathematical in nature. To explain this I shall have to explain some things about the nature of mathematical analysis. You will, I believe, recognize then that warfare has long been receiving some mathematical analysis and that our approach is not terribly radical.

When we have established this background I shall be able to describe to you briefly some of the general and then some of the specific goals of our programs.

The difficulties in this exposition will be largely semantic difficulties. You and I don't always attach the same meanings to the same words. My description of the mathematical process which will follow is required because of these semantic difficulties. The first step in overcoming these difficulties will be in defining two terms which I shall use frequently and whose early definition may allay some misapprehension on your part.

Dr. C. B. Tompkins received his B. S. and M. S. degrees from the University of Maryland, and his Ph. D. in mathematics from the University of Michigan. He was a National Research Fellow at Princeton University and the Institute for Advanced Study from 1936 through 1938. Dr. Tompkins taught at the University of Maryland, Princeton University, and the University of Wisconsin. After Navy service as a Lieutenant Commander, he worked with Engineering Research Associates, Arlington, Va. Dr. Tompkins is presently the principal investigator of the logistics project of ONR at George Washington University.

A system with strict causality is one in which a completely specified set of causes must lead to a single definite result; the result depends on the causes. A probabalistic system is one in which a completely specified set of causes may lead to any of several results; the probability of the occurrence of any result depends on the causes. (I feel that in terms of measurable causes, warfare must usually be considered to be probabalistic. I shall expand this view later, and in particular, I shall later point out that this view encourages a breadth of attack exceeding that of so-called feasibility tests.)

I feel that we also should here agree on the strategic desirability of mounting a series of hammering blows in warfare. No matter what the relative position of the combatants the damaging effect of continuing blows as closely spaced as possible is stressed in much military literature. Added to the classical reasons is one additional reason only recently fully brought home - the possibility of the development by an unharassed enemy of new ordnance capable of profound effect on the outcome of the war.

It is then true that in the critical case, in a war between evenly matched opponents, he who calculates the more accurately and who therefore moves with adequate but not excessive forces and logistics support is expected to win. He is expected to win except for overwhelming misfortune which the best planning can not avoid. In short, his position may not yet be a sure thing, but it is improved. The race is not to the swift nor the battle to the strong; but the betting is best that way; according to FPA in The Conning Tower. Mathematics does not demand a strict causality, and we plan to take FPA's view - expecting from a priori estimates, either of logistics usage or of the outcome of battle, no more than probabilistic accuracy.

Because of the need for mounting attacks as rapidly as possible, logisticians are striving to gain more and more accurate data concerning expected average usage rates. However, it is perfectly well understood that actual usages will be distributed about these averages according to chance, some usage being higher than average, some lower. Safety allowances are common to cushion this effect. And here implicitly is a problem, for, no matter what the accuracy of the recorded usage rates as averages, in each individual case dispersions must turn up. To calculate expected logistics requirements and to add a safety allowance by guess is only one step better, however large that step may be, than to guess the whole logistics requirements. I shall say more about safety allowances at the very end.

Occasionally, the enemy must be engaged under conditions which seem logistically not feasible - in which the average expected requirements are not available. It is striking that two months ago I chose the Guadalcanal campaign as an example of an operation whose a priori justification would be most easily explained in mathematical terms; yet here in the last two weeks I have heard the Guadalcanal operation frequently cited as an example to which mathematical reasoning is not applicable.

In these contradictions I believe that we have different concepts of the nature of mathematics. I believe that there exists a widespread feeling that something like a cold feasibility test must be the end of any

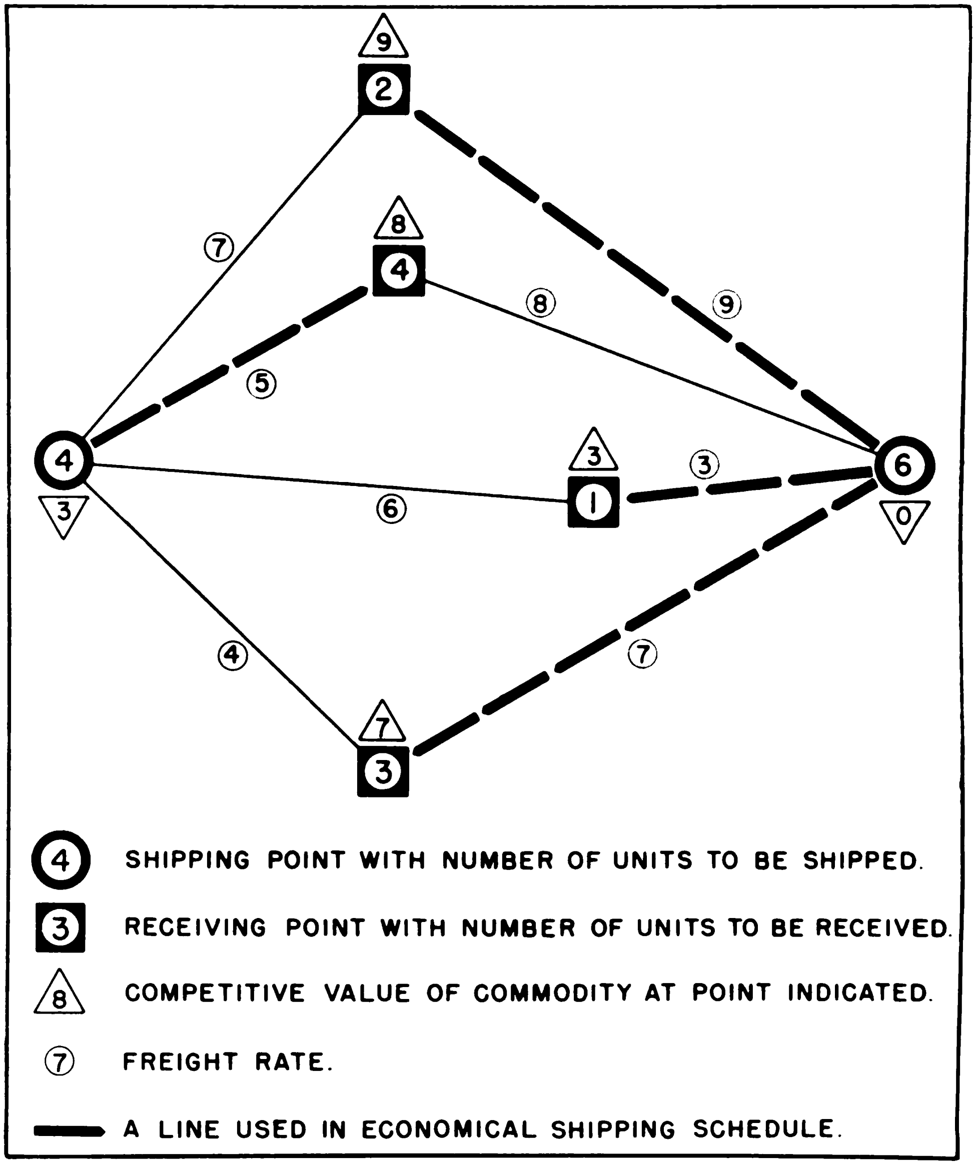

Figure 1. A transportation problem.

mathematical attack. I believe that this is not true. On the other hand, I can see no way to develop an accurate, lucid and quantitative exposition of the place of feasibility tests without using mathematics. I shall explain this statement a little later.

Then what is this mathematics, how will it be applied and how will it affect naval officers?

First, the qualitative answers. The application will not be fast, and most naval officers will know of it only several years from now at the earliest. Second, in Vice Admiral Carney's words, naval officers are experts in sea power and practitioners of leadership. The leadership phase will remain unchanged and still of prime importance. (Good leadership, for example, enhances the potential power of any logistic distribution.) The expert in sea power may be affected in a way analogous to the way doctors of medicine were affected by improved physical aids to diagnosis - the stethoscope, the X-ray, the fluoroscope, the electrocardiograph, the basal metabolism rate meter and a host of other devices. Mathematical analysis will make the naval officer's task harder and more complicated but his results more effective; I fear that it will complicate rather than remove the need for judgement.

Next, negative answers. Mathematics does not replace judgement; it furnishes tools to be used with judgement. It makes it possible for meticulous judgement in some cases to replace blind faith.

Nor is mathematics the study of formulas. Real mathematical information is stated in theorems, not formulas; these theorems may be vastly different from formulas. Here is a mathematical theorem of some value in logistics. It concerns economical transportation of a commodity. The commodity is to be shipped from several sources each furnishing a prescribed amount (two sources, one furnishing 4 units and one furnishing 6, for an easy example illustrated here in Figure 1, but there is nothing to prevent consideration of a vastly larger system). It is to be shipped to several receiving points, each to receive a prescribed amount (four receiving points, in the example, one to get 1 unit, one 2, one 3 and one 4). The freight rate per unit from each source to each receiving point is stated (as in the figure for the example).

THEOREM. A shipping schedule is as economical as is possible if and only if a nominal price per unit can be assigned to the commodity at each shipping and receiving point so that the difference in price between a receiving and a shipping point in no case exceeds the freight rate between them and equals the freight rate on any path actually used for shipping.

This is a theorem with considerable utility, for it turns out that the nominal prices are easily computed and from them a shipping schedule may be written immediately. Without using the theorem an economical shipping program may be much harder to compute. In the figure, one of the family of most economical solutions is shown. The theorem is due in various forms to Tjalling Koopmans, G. W. Brown, G. B. Dantzig, David Gale, H. W. Kuhn and A. W. Tucker. I regret that time limitation prevents my presenting and explaining a theorem in an application without strict causality; useful ones tend to be long and complex.

In passing I should also mention the mathematical technique known as the Monte Carlo technique. It is an example of a technique designed to handle probabilistic problems. Its most spectacular use has been by von Neumann, Ulam and many coworkers on problems of nuclear physics. Nuclear physics, like warfare, has no strict causality.

As a matter of historical fact exactly the Monte Carlo technique has been applied to warfare; one place where this has happened is the Naval War College. The use of the Maneuver Board here applies the Monte Carlo technique to warfare, although not always recording the kind of information we think of in connection with Monte Carlo. You here may be in much the same boat as the character in Moliere's Le Bourgeois Gentilhomme who remarked, "For more than forty years I have been speaking prose without knowing it."

The scientific or mathematical attack may be described in many ways. It might be clearest here to point out the following necessary items in any theoretical treatment of a subject. (Figure 2.) There is first the reality to be studied (whose separation from other reality presents in itself philosophical difficulty). There is secondly a numerical or a verbal model. There is thirdly a logical analysis applied to this model, mathematical if the model is numerical and possibly non-mathematical if the model is verbal. There is finally a translation of the results of this analysis, through the path from the model back to reality, so that the model is tested for realism and so that it may have utility.

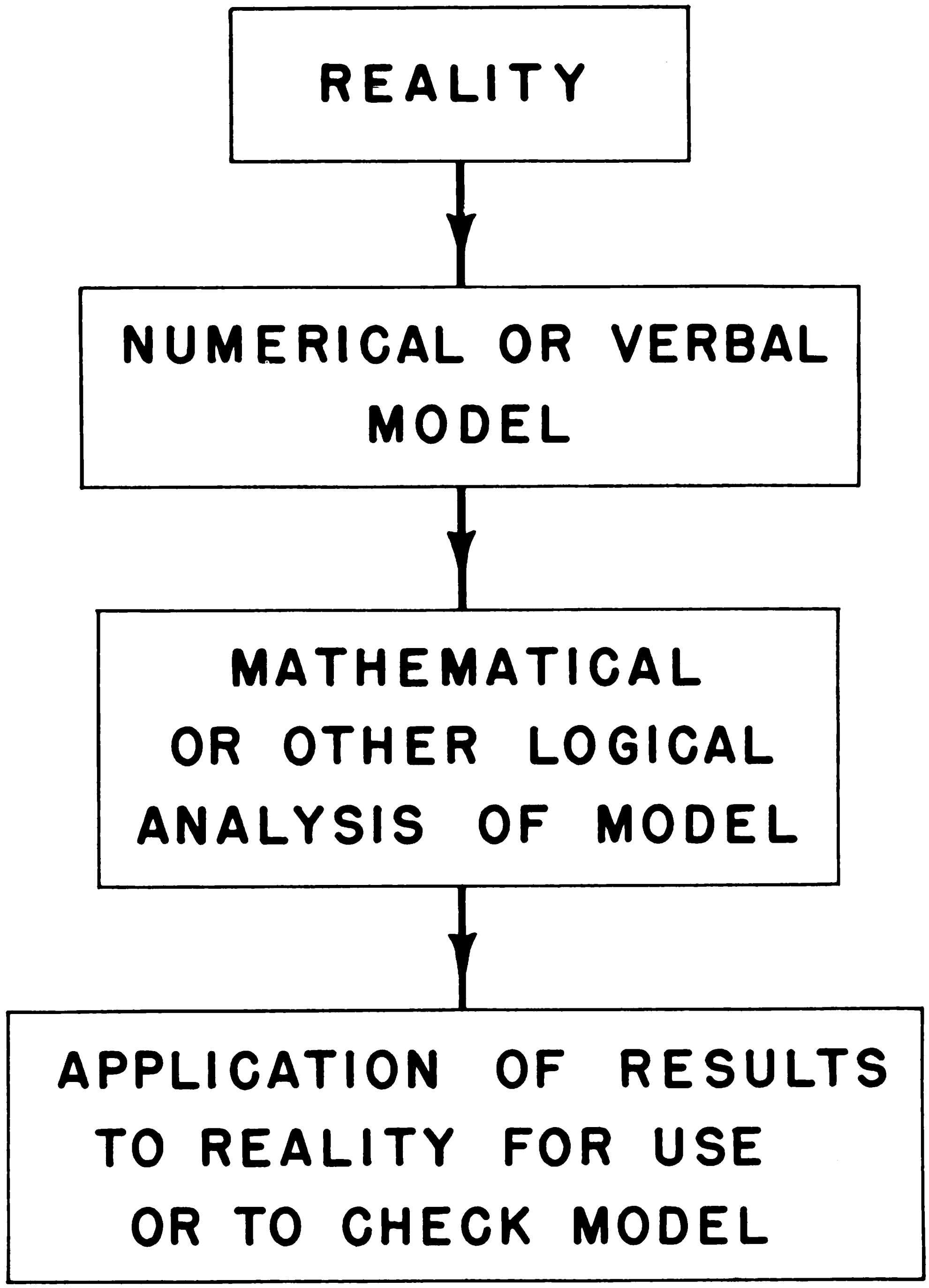

Figure 2. Scientific attack.

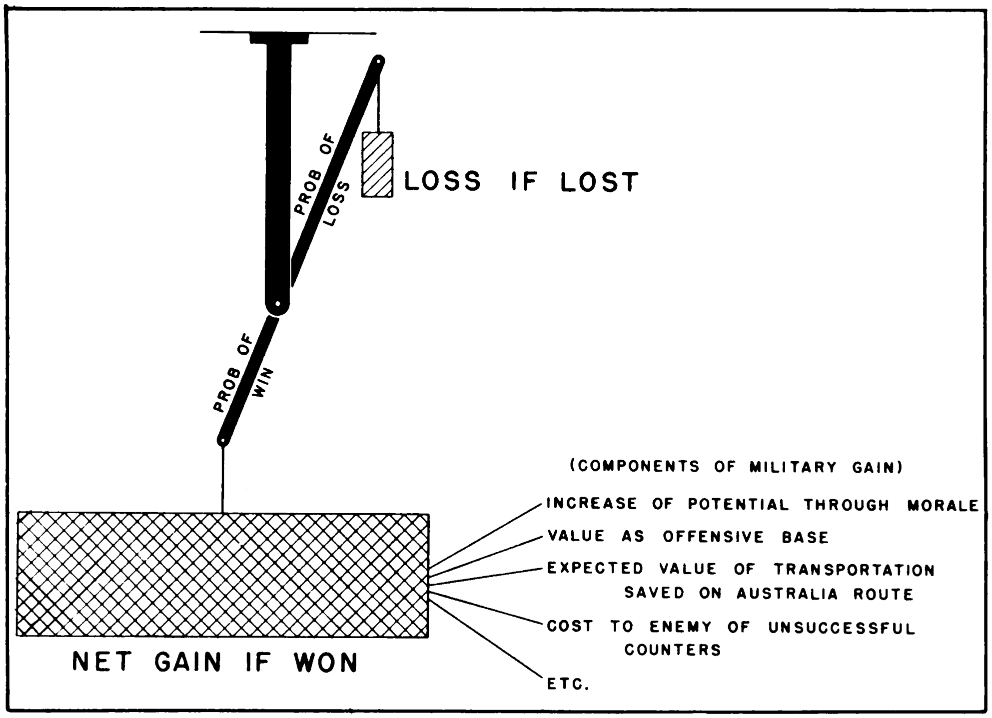

Figure 3. The estimate.

The only abstraction involved is the passage from reality to the model. This abstraction must preserve realism and lead to a workable model. The requirement of a workable model (that is, the requirement of a model facilitating logical and mathematical manipulation) implies that the abstraction is made with as much an eye on the analysis to follow as on the reality which precedes. The danger of error in this sort of treatment lies almost wholly in the definition of the abstraction. The analysis of the abstraction is through classical methods whose validity is almost universally accepted by all except professional philosophers who are interested in the foundations of mathematics.

An abstraction of warfare has already been made. It is contained in the rules for the Maneuver Board. This model and its use is the Naval War College's contribution to the Monte Carlo technique.

It is usual in a theoretical treatment of a science to have several models each representing different regions of reality with acceptable accuracy. In physics, for example, Newtonian mechanics, relativistic mechanics and quantum mechanics are different models, each used in its own region of acceptably accurate applicability. In logistics the feasibility test is a process which may be computationally accurate but which is based on a model of complete causality not universally applicable.

This does not imply that the feasibility test has no utility; its correct use, however, depends on an understanding, possibly quantitative, of the errors which may arise from the use of this model. With this understanding wise choices of proper regions of application can be made.

One further point, and I shall be finished with my description of mathematics. I must introduce the notion of expectancy. This is the only notion which permits one to keep books in a probabilistic world, whether the books be those of a poker shark or of Lloyd's of London.

Any operation whose outcome is probabilistic may have an expected gain. This is what Lloyd's or the insurance company buys from you or sells to you. The expected gain from an operation is the sum of the products got by multiplying the net gains of every plausible outcome by the probability that this outcome will occur. There is sound basis, theoretical and practical, for the statement that your position is improved when you initiate an operation with a positive expected gain. However, the net gains must be expressed in real military values and not in phony apparent values.

I would say that logistics considerations do not determine either the outcome or the expected gain of an operation, but they do profoundly influence the estimate of the probabilities of the various plausible outcomes.

By exercising judgement, in some cases the calculation of expected gain of an operation can be made attainably simple. Such must have been the case for the Guadalcanal operation. Here in a theatre in which our already bad position was deteriorating, the only considerable plausible outcomes of a Guadalcanal operation were victory and defeat. All other plausible outcomes centered around these with net gains insignificantly different. What was required was an estimate of probability of winning sufficiently high that the gain if won times the probability of winning exceeded the loss if lost times the probability of losing. A discouraging feasibility test might have indicated that the probability of winning was not as great as that of losing, but it could not consider the net gains involved. However, a mathematical attack with a different model could. The estimate is illustrated in Figure 3.

Although the theory and practice of expected gain is mathematical to the core, it does not demand here a precise answer. All the precision necessary was what it took to convince the planners that the expected gain was positive; the important thing was the way the balance would swing, not how fast. But mathematics also deals with inequalities, and they describe such situations. Their evaluation had to be based on all material factors and all strategic factors - increase of potential through increased morale, value of Guadalcanal as an offensive base, expected value of transportation saved on the Australia route, cost to the enemy of unsuccessful counters, and the usual host of others, all involving military planning judgement.

Now, I believe the general course which must be followed in any application of mathematics to military problems is clear. A mathematical technique must, in general, involve setting up and analyzing models based on military evaluation, both evaluations of worth and evaluations of the probability of attainment of objective. There is much study now going on concerning military evaluation, logistic and otherwise. Aside from the people who encounter these problems in routine technical assignments, the following groups have set up study projects:

Weapons Systems Evaluation Group (Secretary of Defense),

Rand Corporation, (treating many aspects of the problem under U. S. A. F. contract), OEG (U. S. N. Contract with Massachusetts Institute of Technology),

ORO (U. S. A. Contract with Johns Hopkins University),

The advanced colleges of the Army, Navy, Air Force and Combined Services,

Project SCOOP (Air Comptroller USAF),

Office of Naval Research.

There are probably many others.

A still general, but more nearly specific goal and an enormously important one is to prepare the way for the use of the high speed electronic data handling equipment now being developed. This is a huge job requiring considerable judgement and mathematical ability. The machines may carry out as many as a thousand multiplications per second; but for them to do this effectively the way must be made clear for them. At present the numbers to be multiplied, even if the general scheme of the calculation remains unchanged, are in various places and those in the same place are in various units, long tons and short tons for example. The white field of routine calculation is now cluttered by black spots requiring judgement (Figure 4). The electronic equipment is worth acquiring only if it can travel a long path without encountering one of these spots. They must be meticulously herded together, and in the remaining white field the data handling equipment can function effectively. Thus, accepting the idea of a feasibility test, the test can be shortened both in time and the number of people and sections consulted; its reliability can be increased by increasing the detail which can be handled and by setting up automatic checks of, and possibly adjustments to, the usage factors listed. This can be started immediately; it will be started probably using punched card equipment to set the routine. To accomplish this all that is necessary is the collection of tremendous quantities of data, the modification of these data to fit a standard pattern using standard units, and the formulation of a rigid menu a few million operations long for a machine.

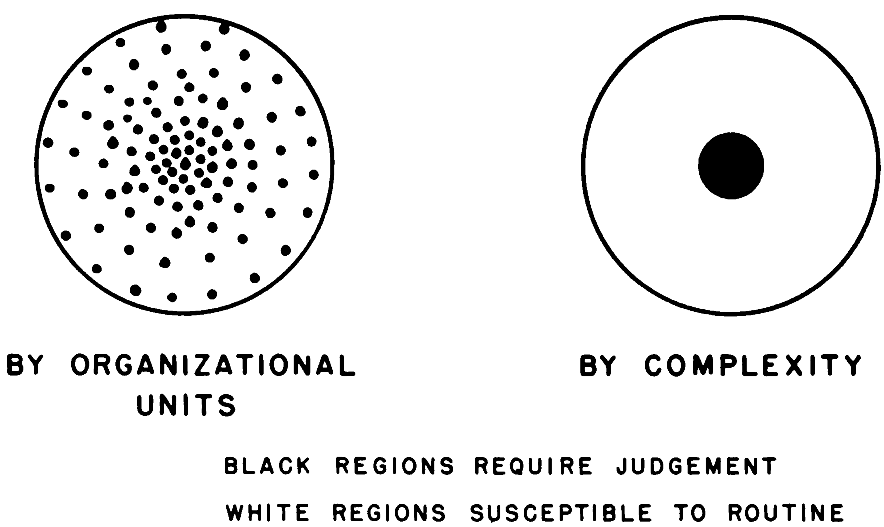

Figure 4. The calculation problems of The Department of Defense.

Problems of optimal choice are in the long run the problems which must be solved. They are more important and more difficult than problems of estimating expected usage. Some can be and will be attacked immediately. Some, such as the transportation problem mentioned earlier have already been attacked. Selection of one plan over an alternate is equivalent to assigning figures of merit sufficiently accurately to choose the higher (this is the evaluation business again). If one thinks in terms of a split between strategy and logistics, military specialists may assign an expected strategic value and an expected logistic cost. (This is a sort of quantitative estimate of suitability and feasibility, which are terms more familiar to you.) The comparison between these (the acceptability) is difficult, but in many cases the strategic values for two plans are the same (or nearly the same) and one need only choose the optimal logistic plan. Floating bases must be compared with other advanced bases, carrier fighter support with overseas land based fighter support for transoceanic bombing missions, and so on. In others the logistics cost is fixed; planners must choose the optimal schedule of advanced base construction with the transportation and construction facilities available, for example, and to do this they must solve a difficult problem depending on the expected value of each base (for every plausible extent of completion at every time) as a support for military operations. I believe mathematicians can help military planners assign this value and carry out the calculations exhibiting the best that can be done logistically. This help might include an estimate of the degree that minor changes in input affect the output, for example; in some cases it may turn out that the output is highly insensitive to variations in input evaluations and the optimal plan can be determined with great confidence.

Finally we shall start an investigation of estimates of reliability and of means of computing a safety allowance. Only the first short steps are clear. Here, the departures of logistics and naval science from strict causality must be carefully evaluated.

An example will illustrate the concepts which must be evaluated. This example will have two parts, one with strict causality and one probabilistic; each part will have the same average usage rates and the illustration will be of the differences in required allowance because of the safety allowance in the probabilistic case. Numbers have been kept small, not for arithmetic convenience but to exaggerate these differences.

Both problems concern cake baking as it relates to procurement of butter and assignment of cooks with obviously unrealistic usage factors. If in a strictly causal sense each pair of cooks can produce one cake with two pounds of butter, if butter is procured in half pound units, and if four cakes are required, then procurement of sixteen units of butter and assignment of eight cooks are clearly necessary and sufficient to meet the program.

If, on the other hand, cakes are to be baked at home under conditions of extreme unreliability, a more involved calculation is necessary. Let butter again be the critical item, and assume that it is to be procured by sending children to the store. Each child is sent for one pound of butter, but the chances are one out of two that he will return with a pound of butter and one out of two that he will return with a Yo-Yo, useless for baking cakes. Thus, on the average, each child returns with one half pound of butter and, on the average, a child as a fundamental unit of procurement is equivalent to the half pound of the preceding example with strict causality.

In the same way, suppose that a wife armed with a pound of butter and sent to the kitchen to bake a cake has one chance out of two of producing a cake and one out of two of producing some sort of inedible mess. Again, the average is two pounds of butter and two wives (cooks) per cake. Now, however, no matter how many children and wives you assign to the task you can never be certain a priori that they will produce as many as four cakes. You can assure yourself to any extent short of complete assurance, however, at a cost (which again is the basic cost which Lloyd's will charge); thus, it turns out after some calculation that you can produce a 90% probability of obtaining at least four edible cakes by assigning about 21 children to the butter mission and by assigning 12 wives to stand by to cook if enough butter is procured. These numbers are not firm either, for (in general) you can reduce the number of children required a little by assigning more wives; the final choice must be determined by a simultaneous consideration of the relative cost of the assignments and the dependence of the probability of success on the numbers assigned. The number of wives was minimized (avoiding fractional wives) above. If there are only 11 wives, there is less than a 90% probability of at least 4 cakes even if each is certainly supplied with butter.

Thus, in summary, the average production rates indicate 16 procurement units of butter and assignment of 8 cooks in either example. In the first example (with complete causality) this assignment gives complete assurance of success and no safety allowance is needed or useful. In the second, an allowance of 5 additional procurement units of butter and 4 additional wives give 90% assurance of not less than the required output.

It is clear that in this second problem one would immediately search for additional causal parameters - variables which would make possible predictions concerning children's behavior or cooking results with more than 50% assurance. Until some such parameter is found, however, the most that can be done is the provision of the most economical safety allowance consistent with the observed dispersion of results and the demanded probabilistic assurance of success. The picture is the same if we talk airplane engine parts, vacuum tubes or cruisers. Without an accurate picture of both average usage and the distribution of actual usage around this average we get failures and a provable high probability of paralyzing bottlenecks. In many cases good estimates of these distributions may be made soon and a procurement policy properly established.

ACKNOWLEDGMENT

I should like to express my appreciation for the advice which I received from many officers and, in particular, my gratitude to Capt. Henry E. Eccles of the U. S. Naval War College.

On the Naval Research Reserve

First VRR Unit in New Mexico Activated

CAPT T. L. Wogan, USN, Officer-in-Charge, Naval Training Center, delivered the welcoming address at formal activation ceremonies on November 30, when approximately 35 naval reservists in Albuquerque, N. Mex., formed the new Naval Research Reserve Unit 8-7.

LCDR A. F. Medbery, USNR Reserve Program Officer for that area, discussed "Relationship of the Albuquerque Research Reserve Unit to ONR."

The Commanding Officer of the new unit, LCDR Sherman A. Wengerd, USNR outlined the purposes and programs of the Albuquerque Unit, and introduced the principal speaker of the evening, Dr. Kirtley F. Mather, professor of geology at Harvard University. Dr. Mather had as his subject "Natural Resources and National Preparedness," in which he presented a lucid analysis of the country's natural-resource position in the community of nations, and our dependence upon the natural resources of other nations.

Further activities for the first quarter of 1950 were discussed in a business meeting on December 14. Albuquerque is the first unit in the 36th state to become an active member of the Volunteer Research Reserves. Welcome aboard!

Pictured at the activation of VRR, Unit 8-7 at Albuquerque, N. M. on November 30, are left to right: LCDR A. F. Medbery, VRR, Program Officer for New Mexico & Eleventh Naval District; CAPT T. L. Wogan, Officer-in-Charge, USNR Training Center, Albuquerque, N. M.; Dr. Kirtley F. Mather, professor of geology, Harvard University, guest speaker; and LCDR S. A. Wengerd, Commanding Officer, Unit 8-7.

News and Notes

- FLASH: The Third Annual Research Reserve Seminar, to be held in Washington in June 1950, has just been approved. See the February issue of Research Reviews for details.

- Ensigns commissioned prior to 31 December 1946 have been recently promoted to Lieutenants, junior grade, by order of the Secretary of the Navy. All those concerned are urged to execute the Acceptance and Oath of Office of their new rank as indicated in NavPers 15805 at Commandants' offices or any other Naval activity.

- The functions and personnel of Code-104, Naval Research Reserve, have been transferred to the Office of the Assistant Chief for Administration. Code designation for this activity is now Code-230.

- Have you informed BuPers of your latest change of address? In accordance with Navy Regs, Article 1233 "Every officer...when not assigned to a duty station, shall report his address as of 1 January of each year to the Chief of Naval Personnel." All changes after that date should be reported as they occur.

- Have you been sworn in to your new permanent rank? New promotion lists are published from time to time; write to your nearest naval activity for the latest information.

- Have you applied for your uniform gratuity? Reserve officers are entitled to $50.00 uniform gratuity every 4 years. The form, which must be submitted in triplicate to BuPers, is as shown on page 30.

ONR Scientists Address Units

Renewed interest and activity of the older VRR units this fall, and the activation of new units have brought about an increased demand for personal assistance from ONR-Washington.

Admiral Solberg, Chief of Naval Research, spoke informally to the officers of VRR Unit 9-1 at Chicago on October 24. Although the regular meeting night was changed to coincide with Admiral Solberg's time in Chicago, a good attendance was reported and the off-the-cuff talk was received with enthusiasm.

CAPT C. W. Shilling (MC) USN, Deputy of Bio Sciences, ONR-Washington, spoke on "Submarine Medicine in World War II" to the Reserve unit at Purdue University in October, to the group at Camp Detrick, Md. in November, and to the VRR unit at the University of Virginia on December 7.

In November Dr. Roger D. Reid, Head of the Microbiology Branch, ONR-Washington, spoke on "Research in Biological Warfare" to the members of VRR Unit 13-5 at Corvallis, Ore., and to VRR Unit 12-3 (Biological Sciences) at Berkeley, Calif.

Dr. T. J. Killian, Science Director and Deputy for Research, ONR-Washington, addressed the members of VRR Unit 13-1 at Cornell University Medical College, New York City, on Thursday, December 15. Among other things he discussed the program for the future of the Research Reserve in its relationship with the Department of Defense.

Representatives from ONR-Washington have expressed interest in and willingness to cooperate with the Research Reserve program by consenting to speak at meetings of the nearest VRR units, when travel schedules permit. When feasible, the Deputy of the ONR group concerned will write the Commanding Officers in the cities to be visited, so that a program can be arranged accordingly. A copy of this letter should be forwarded to the Reserve Program Officer in the area concerned and to the Director of the Research Reserve in Washington for possible briefing of or further arrangements for the speaker.

It is suggested that Commanding Officers who would like to have certain speakers from ONR-Washington, or to have specific subjects discussed at the VRR unit meetings, communicate directly with the Deputy of the pertinent ONR Group, sending a copy of the letter to the Director, Research Reserve, and to the Program Officer. In this way it is believed that the services of ONR-Washington can be utilized to the fullest extent in providing speakers for Research Reserve meetings.

APPLICATION FOR UNIFORM GRATUITY

Date ________________

From: ____
Surname First Middle Rank File Number

To: Chief, Bureau of Naval Personnel,
Finance and Material Division,
Washington 25, D. C.

Subject: $50 Uniform Gratuity.

Ref: (a) ALNAV 14-45.

1. I hereby submit claim for payment of Fifty Dollars ($50) Uniform Gratuity, having last been entitled to a uniform gratuity of ____________ ($100 or $50) on __________ (date), and having performed active duty continuously since __________ (date), except as follows:

____
(State periods of active duty separately as occurring if not continuous,
____
or insert none.)

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Must be filed in triplicate. ______________________
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