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MR. DETONATION SCIENCE FOR DOD:
SIGMUND J. JACOBS

By Ruth Doherty, Jerry Forbes and James Short

Sigmund J. Jacobs, 93, an internationally recognized authority on explosives with the Naval Surface Warfare Center, died Feb. 25 of pneumonia at the Sunrise assisted living facility in Silver Spring. He was a devotee of classical music, opera, and ballet, and was known for entertaining family and friends with magic tricks. His wife of 63 years, Lillian H. Jacobs, died in 2004.

Sigmund J. Jacobs was born in Minneapolis and received a bachelor's degree in chemical engineering in 1933 and a master's degree in physical chemistry in 1952, both from the University of Minnesota. In 1942, he joined the staff of the Explosives Research Laboratory, Pittsburgh, to work on deflagration and detonation in condensed media. He joined the Naval Ordnance Laboratory in 1945 to establish a group to study detonation and related explosives problems. In 1950, NOL sent him to the van der Waals Laboratory, University of Amsterdam for a year to study Molecular Physics. His work there on "Rapid Expansion of Dense Gases," earned him the PhD in Physics in 1953.

Dr. Jacobs held a number of positions at the NOL weapons research facility, including technical coordinator of the program that developed the Trident missile. His expertise was in explosives and propellants. He was a Life Fellow in the Society of Motion Picture and Television Engineers for his invention of the "Jacobs" Camera. Sig was one of the founders of the International Detonation Symposium, which has been held every four years since 1966. At the time he retired in the late 1980s, he was senior research scientist at the NSWC, White Oak facility. In 1998, the detonation science facility at Naval Surface Warfare Center at Indian Head, MD was named in his honor.

Dr. Jacobs showed that he had ingenuity as a basic skill early in his life as illustrated by the story he told Jim Short on how he funded his way through the University of Minnesota. He would visit photo-processing studios in the Minneapolis area and volunteer to provide them a service disposing of their waste photo processing solvent. He would appear every week to collect the solvent and leave. What the photo processors did not know was that Sig took the solvents home and separated the silver etched from the film during the processing sequence. He collected and sold sufficient silver each week to make it through the University of Minnesota.

Much of his career was before hydrocode material models and approaches where fully developed so good thinking had to be used to attack the complicated problems. Dr. Jacobs approach to problems was to look for the dominant physics and/or chemistry of the problem and then make informed and reasonable estimates for the solution. He was respected for this straightforward physics approach. Among his many contributions to detonation physics were: (1) the Kamlet-Jacobs equations for predicting detonation parameters, (2) Jacobs-Roslund equation for predicting initiation of cased explosives, and (3) equation of state for detonation products.

Discussing these contributions from three perspectives will illustrate the diversity of contributions that Dr. Jacobs made to detonation science, the Navy, and the Nation. The perspectives are: (1) his technical leadership, (2) his contributions to experimental techniques, and (3), his theoretical and approximation contributions.

Technical Leadership

He presented one of the earliest detonation wave papers given at the May 1947 Washington D. C. American Physical Society meeting [Ref. 1]. In this presentation, he observed that detonation velocity was the only parameter measured with precision at that time. He pointed out that to obtain more definite knowledge concerning the state of the product gases, it was desirable to measure particle velocity and/or temperature. Subsequently he developed optical methods to measure particle velocity behind shocks and detonation waves. Temperature measurement in a detonating explosive remains a 21st century challenge. Sig also gave a number of the early review papers on the science of detonations in 1960 [Refs. 2-4].

Throughout his career Sig sought to make accurate particle velocity measurements behind the detonation front. He discovered that a new electromagnetic method for measuring particle velocity in low conducting material was published in Russia in the 1960's. Prof. Dremin and colleagues in Russia had successfully used this new accurate experimental technique for particle motion measurements behind detonation waves. This technique used the fact that a thin foil moving in a magnetic field creates a voltage across the foil that is directly proportional to the foil velocity cutting the flux lines. This is a measure of particle velocity behind detonation waves for embedded thin foils. Sig had his colleagues at White Oak adopt this technique for use on Navy explosives in 1970. This was the first time this gauge was used in the U.S. [Ref. 5]. This gage is now used in many shock wave and detonation physics laboratories in the U.S. It remains the main gage for conducting detonation research at Los Alamos.

Sig came to NOL in 1945 to form a group to study detonation physics and chemistry. He actively participated in getting the group to work on key problems. Sig led the efforts for the Navy at NOL throughout his career. Colleagues within the Navy and outside the Navy consulted him. His colleagues in this international field respected him as one of the pioneers of detonation physics. The list of references illustrates some of Sig's major contributions to the field. Three widely recognized ones are (1) his part in developing the equation of state called JCZ for detonation products [Ref. 6] which is still used in many hydrodynamic codes, (2) His development of the Jacobs-Roslund equation for predicting initiation of cased explosives [Ref. 7], and (3) his part in developing the Kamlet-Jacobs equations for determining detonation wave properties of different explosives [Ref. 8]. He also made major contributions by his willingness to share his ideas with all colleagues.

Many colleagues recognized the importance of many of his unpublished ideas and would later publish papers crediting Dr. Jacobs for these contributions.

In a January 1966 memo [Ref. 9] Sig and Donna Price presented a research program plan for NOL in the area of physics and chemistry of detonations. They pointed out that it was exactly 20 years from this date that the Naval Ordnance Laboratory organized its Explosive Research Program. The decision to establish this group at NOL was largely influenced by the efforts of Dr. Steven Brunauer who was keenly aware of the fact that the U. S. had built up a capability in the field during World War II by drafting capable researchers from the various universities, and that this capability appeared to be quickly dissipating with the return of these men to their universities at the war's end. Dr. Brunauer felt that a continued capability and advancement of knowledge in explosives was an absolute necessity for the continued readiness of the Navy, in particular, and the entire defense community as well. Not only NOL and the Navy recognized the need for explosives research. The Army continued a group in this field at the Ballistics Research Laboratory, Los Alamos Laboratory increased its explosives research when the Atomic Energy Act was passed, the Naval Ordnance Test Station (China Lake) built a group for this technology, Stanford Research Institute started a group, and the new Lawrence Livermore National Laboratory was working in this area.

This memo reviewed the history of NOL in explosives research from 1947-1966 and then presented the problems of the technical field with a special view of what the Navy needed. It made a strong point that specific short-term goals needed to be met but to solve unknown problems that would arise in the fleet required developing knowledge in areas that did not have a specific current application. Funding of this basic knowledge in detonation science has always been difficult to obtain but occasionally large programs such as the High Energy Propellant Safety program, which Sig managed, came along that needed detailed knowledge of propellants. These programs allowed flexibility for obtaining basic knowledge. Part of Sig and Donna's plan was to have research that could be published which is necessary for recruiting and retaining good scientists that could keep the laboratory aware of the technical issues of this field.

In the conclusion of this memo, Sig and Donna expressed a summary view of the NOL program. *"We have tried to express the view that we should be slanting the work toward Navy and DOD goals; that does not mean we should restrict our effort only to the short range problems. The selected problems to work on should have the purpose of plugging holes in our knowledge, the holes considered to be the biggest first; and that we aim to keep a step ahead of the questions by maintaining an awareness of the pertinent literature."*

In 1951 the Navy recognized the need for a forum for detonation scientist to discuss their work and began with a meeting of just a few papers. This meeting has grown into the large International Detonation Symposium. The detonation symposium remains recognized as the premier detonation science meeting in the world. Sig was the chairman of the symposium for twenty years. He was chairman from the time the decision was made in 1963 to open it to unlimited international participation (4th symposium was held in 1965) through the 7th symposium in 1983. He was honored at the banquet of the 8th symposium in 1989 where he was presented a sheepskin scroll summarizing his contributions to the symposium and detonation science. Ruth Doherty announced at the banquet of the 13th symposium earlier this year that an award in Sig's name will be made at future symposia.

An interesting insight into Sig's leadership for the nation is best presented by a story he told Jim Short in answer to Jim's question why has the Navy continued to manage the Detonation Symposium. Sig turned over the chairmanship of the Detonation Symposium to Jim Short in the early 1980's. Subsequently, Jim asked Sig why White Oak was the continuing chairman of the Symposium, which only made sense so long as White Oak was preeminent in explosives as it was at the end of World War II. It appeared to Jim that the greater conventional expertise might be elsewhere. So it would not be unreasonable for other organizations to think they should have the Chairmanship. In response to this question Sig told Jim the following story.

"The Lawrence Livermore Laboratory opened in 1952. It was a nuclear physics lab, so naturally the leaders, symbolized here by Dr. John Foster, staffed it with nuclear physicists. Shortly after opening, the physicists remembered that conventional explosives were needed before the interesting nuclear events could begin. They looked for their conventional explosives expert only to realize they did not hire any.

Livermore looked to their colleagues at Los Alamos for help in developing this technology. For reasons Sig could not be sure of, Los Alamos declined to help. So, Dr. Foster turned to White Oak's Naval Ordnance Laboratory, which was clearly the other preeminent detonation lab in the nation at the time. The NOL leaders met to discuss how to respond to Dr. Foster's overture. There was debate. Some wanted to follow the Los Alamos lead, and pass. The concern of some was that given the large budget of Livermore compared to the NOL budget, it would not be long before Livermore surpassed NOL's conventional explosives expertise.

Sig recalled that others agreed with that observation, but Sig felt it was NOL's duty to the nation to voluntarily make the decision to become the teachers, knowing that it was inevitable that in time the students with superior resources would surpass the teachers. Sig Jacobs was named the NOL leader for what came to be known as Project Lace. For several years in the early 1950's, Livermore funded 8 man-years of work at White Oak. Seven of the man-years were done at White Oak. There was always one White Oak person at Livermore as the Project Lace liaison. The liaison person was there for six months. Among those assigned to Livermore were Jules Enig, who brought Jim Short to White Oak, and Hy Sternberg, who many of us worked with at White Oak.

Sig believed that the self-fulfilling prophecy played out as assumed. In just a few years Livermore's conventional explosives expertise equaled, maybe surpassed, White Oak's expertise. Sig said after that came to pass, like teenagers, the Livermore" children", did not always treat their NOL teachers with dignity and respect. But the teachers were wise and felt good that when their nation needed them to teach, they taught well."

The tradition of Livermore turning to NSWC for help continues from time-to-time. The most recent transplant from NSWC to Livermore was Jerry Forbes. White Oak remained a preeminent explosives and research lab up to closure of the site in 1997. Livermore and now Indian Head continue to collaborate in the spirit taught by Sig. Jacobs.

Experimental Techniques

Sig developed experimental techniques and instruments to accurately measure detonation wave parameters. In 1957-1958 he developed and published a paper on the NOL wedge sensitivity test (Ref. 10] for measuring run distance to detonation for a given input pressure. Sig credits the streak camera used on the wedge test as a major step forward in measuring detonation wave parameters at that time.

One of the most useful instruments for explosive's detonation and sensitivity research at NOL was the high-speed focal plane-framing camera [ref.11]. This "Jacobs" camera produces 216 frames in 1/8 revolution of a rotating mirror, producing over one million frames per second. This camera provides the combination of high speed with precise time definition. The significance of this achievement was recognized by Dr. Jacobs receiving the E. T. du Pont Gold Metal Award in 1964. This camera has proven indispensable in conducting experiments including the modified ignition gap test, underwater explosive sensitivity test, projectile impact studies, and focused blast studies. He also co-authored a paper on how the Jacobs camera can be used for detonation science experiments [Ref. 12]. To go along with the high-speed photography Sig and co-workers also developed a shot-duration light source to substitute for a spark gap in schlieren or shadowgram photography [Ref. 13].

Theoretical and Significant Approximations

Sig published a number of papers on the equation of state for detonation products [Refs. 14-15]. He followed up this work by contributing to the Jacobs-Cowperthwaite-Zwisler (JCZ) equation of state for detonation products that is still used in hydrocodes today [Ref. 6].

Prior to the time when hydrocodes could accurately and inexpensively assess safety scenarios, Sig came up with a formula for determining if a bullet/fragment would initiate detonation in a cased munition. This was later refined by Les Roslund and is known as the Jacobs-Roslund equation [Ref. 7]. This equation is still in use today for fast and reasonable assessments of whether fragments will detonate a cased explosive. In fact, a revision of this equation has come out from ARL this year (2006) that allows for fragment tilt and shape to be accounted for in this equation.

The Kamlet-Jacobs equation [Ref. 8] for estimating Chapman-Jouguet detonation properties was developed. This equation assumes what the key chemical pathway of the products of CHON explosives. This equation is still used for quick predictions of the probable detonation properties of new molecules.

With the emergence of the personal computer, in his final working years even Sig turned to hydrocodes and numerical solution of partial differential equation such as the Navier Stokes equations. After his retirement Sig worked part-time. First he was a re-employed annuitant then became a contractor. Jim Short recalls Sig using a computer whose input required paper tapes to integrate the compressible flow equations. But even then, instead of letting the computer crunch away calculating all the terms in the equations, Sig would use his physical insights into the problem to determine which terms were so small as to be negligible. Sig would monitor the solution, turning terms off and on as they became negligible and then became relevant again. He ended his career as he began it, using good thinking to solve complicated problems.

Select papers

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15. Sigmund J. Jacobs, “On the Equations of State of Compressed Liquids and Solids,” NOLTR 68-214, 15 December 1968.