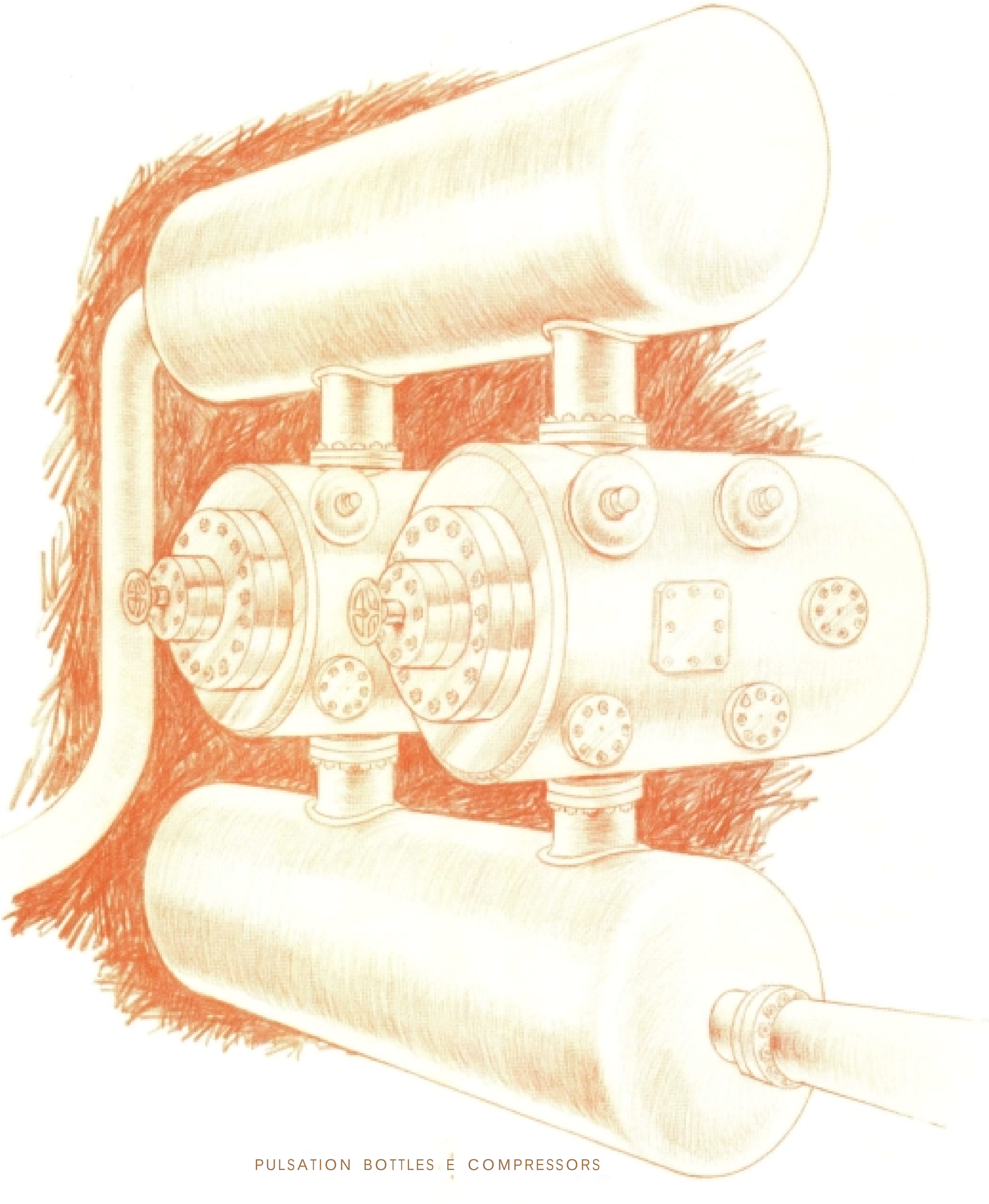
The American Society of
Mechanical Engineers

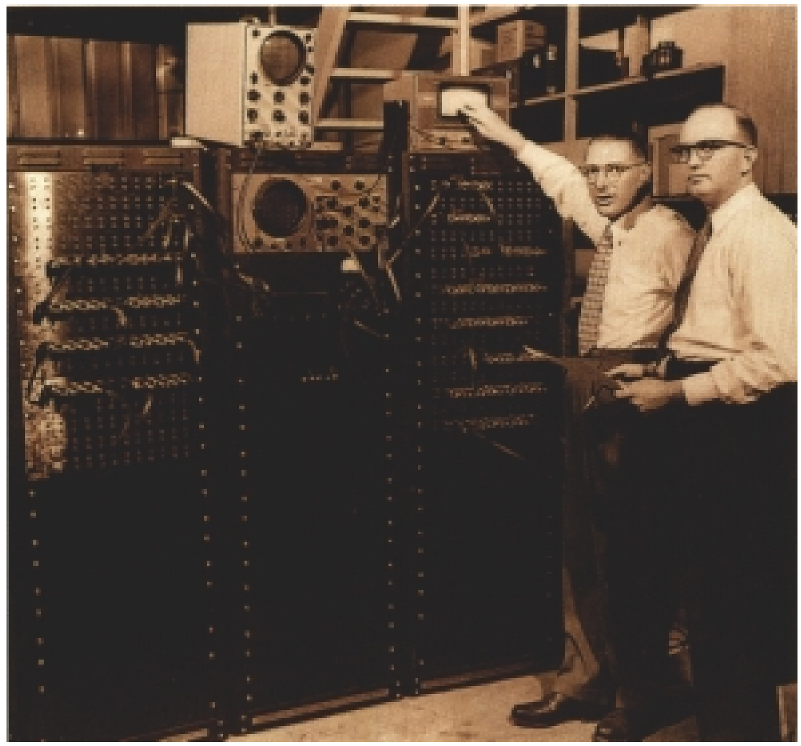
Southern Gas Association Analog

A National Historic Mechanical Engineering Landmark

Designation Ceremony
Southwest Research Institute
San Antonio, Texas
August 17, 1990



PULSATION BOTTLES E COMPRESSORS



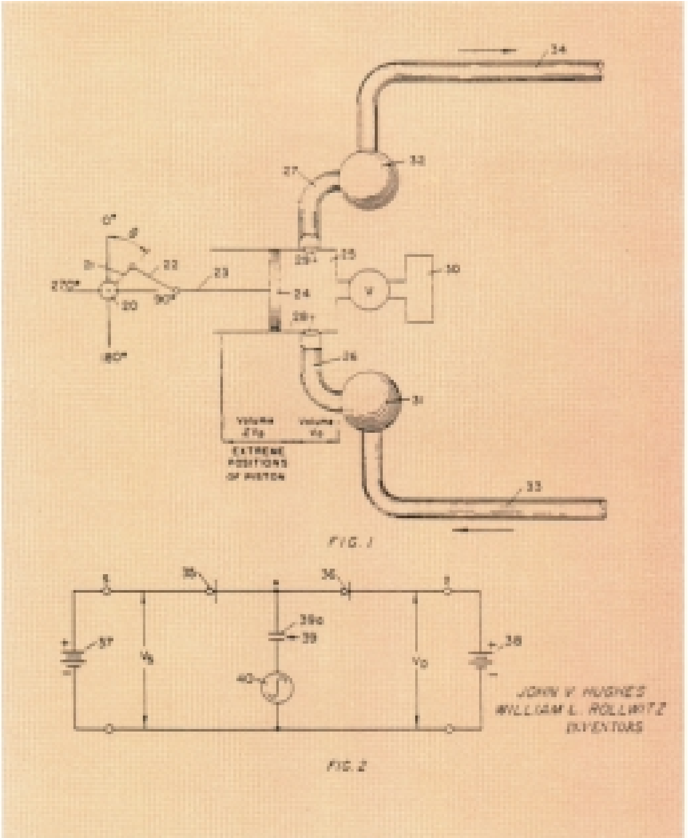
The Southern Gas Association's analog is an example of American technology successfully applied to meet a critical worldwide need. The analog, first successfully demonstrated in 1955, was the first device of its kind applied to gas pipeline systems, and it remains the most widely used of fewer than a dozen similar tools — most of which are licensees of the original technology.

The analog helped the gas industry achieve a safe, reliable market expansion for natural gas as a fuel for heating homes and businesses, for generating electrical power and process steam, and for gas turbine mechanical drives. With relatively low carbon dioxide output, natural gas has become the best fuel option to safeguard the world's environment.

The group that collectively owns the analog technology, the Pipeline and Compressor Research Council (PCRC) of the Southern Gas Association (SGA), numbers more than 70 members from 10 nations. Every major U.S. gas transmission company is a member, as are many major oil companies and most European gas companies.

Notable engineering applications of the analog include the Alyeska Pipeline that brings North Slope oil down through Alaska, the first CO_2 pipeline built for Canyon Reef, the first — and probably the largest — reciprocating compressor high-pressure gas reinjection system on the Statfjørd production platform in the North Sea, and a major expansion of Chevron's Pascagoula refinery to help with the production of lead-free gasoline.

Dr. J. Victor Hughes (left) of Southwest Research Institute and Edward Henderson, former PCRC chairman, contributed to the development of the original analog that began solving problems for the gas industry within 36 months of its inception. The engineers are seen here with the analog as it was in 1956.



Designing safe and reliable natural gas compressor stations once was a hit or miss proposition. Understanding the interaction of the complex maze of compressors and pipes of varying diameters and lengths defied even the best designers. For want of a better technique, they were forced to adopt trial-and-error methods. The results were often unsuccessful and sometimes costly and dangerous. The gas pipeline industry was in a difficult position — needing to expand facilities rapidly, but unable to do so safely and efficiently.

Page One of the gas pumping system analog patent application, Number 2,951,638, filed on May 31, 1955

Historical Significance

When the American natural gas industry began to flourish after World War II, finding a way to reduce the vexing problems of vibration and pulsation became imperative. In 1952, the Pulsation Research Council — which later became the Pipeline and Compressor Research Council — brought the problem to Southwest Research Institute (SwRI), then in its sixth year of operation. Development work began that same year, and in 1955 the SwRI engineering staff successfully demonstrated an analog simulator that solved the problem by making it possible to model the transient flow interactions between compressors and attached piping. Guesswork in engineering designs was now replaced by accurate engineering data.

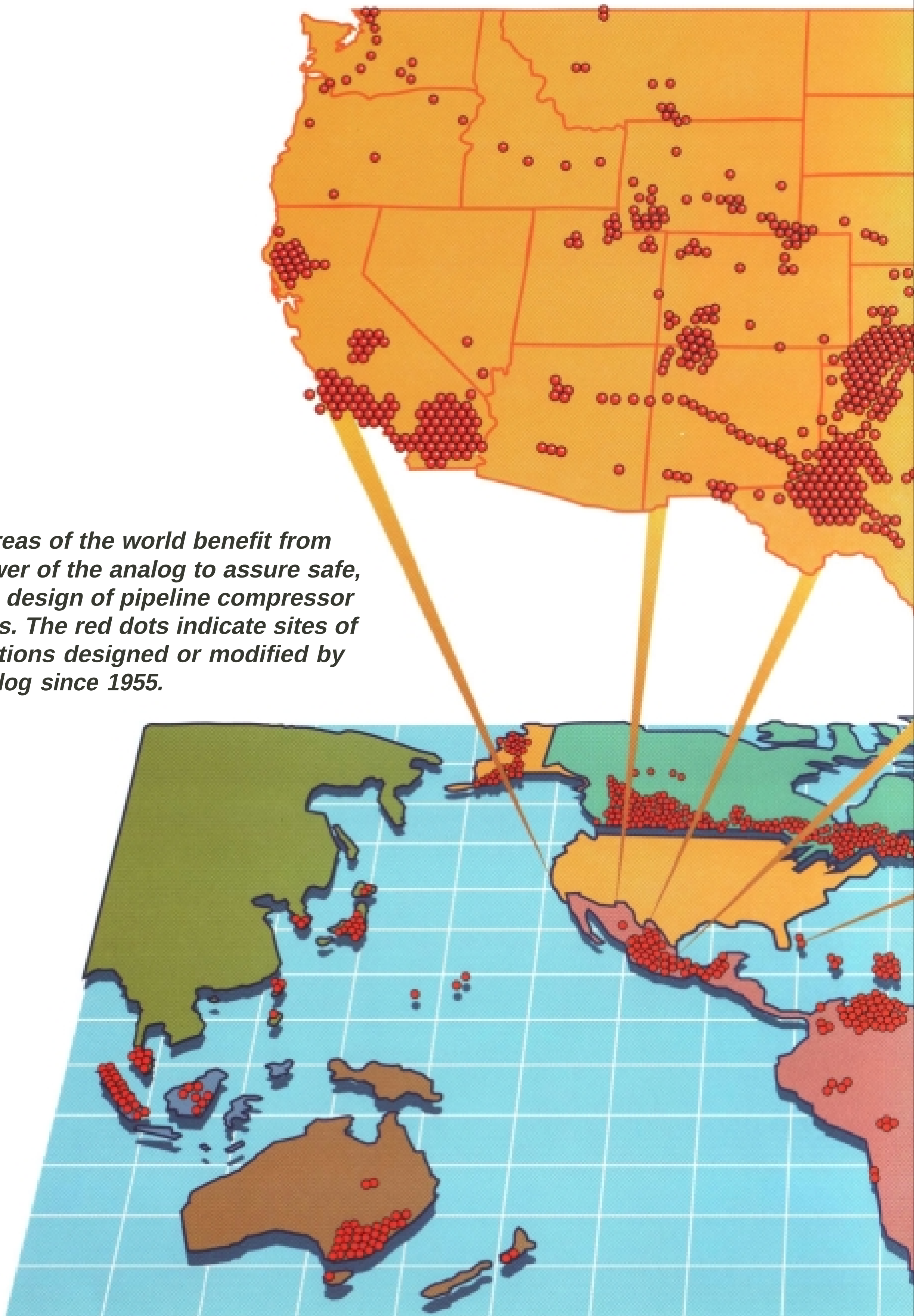
From the beginning, the analog contributed to the safe and reliable mechanical design of pipeline compressor systems and became a significant factor in the rapid expansion of the nation's pipeline system. Without it, the remarkable safety record of the gas transmission industry would have been jeopardized.

The analog still relies on the same fundamental engineering concepts that led to its initial

PCRC steering committee members and technical advisors on the analog project in 1953 included (top row, left to right): Dr. J. Victor Hughes, SwRI; Edward Henderson, Arkansas-Louisiana Gas; Tom Pofahl, El Paso Natural Gas; Ralph Bain, Arkansas-Louisiana Gas; Paul Erlandson, SwRI; O.H. Moore, Tennessee Gas; Glenn Damewood, El Paso Natural Gas and later SwRI; (bottom row, left to right) Tom Novosad, Tennessee Gas; Ben Perry, Cooper-Bessemer; Mendel Heller, United Gas; and Fred McNall, Clark Brothers.

success, and it continues to be used in the design of as many as 150 systems a year. Analog applications have steadily expanded beyond the pipeline industry to the chemical, petroleum, and nuclear industries. To date, more than 10,000 installations have been created or modified using analogs to solve the complex acoustical equations defining the flow of gas and generation of pressure pulsations by using electronic equivalents of pipe, compressors, and natural gas.

Most areas of the world benefit from the power of the analog to assure safe, reliable design of pipeline compressor systems. The red dots indicate sites of installations designed or modified by the analog since 1955.



Description

The landmark analog is located on the lower level of an SwRI laboratory and office area dedicated to the operations of the PCRC Center for Applied Machinery and Piping Technology (CAMP$_T$). The building houses the Mechanical and Fluids Engineering Division, one of twelve SwRI operating divisions, and is sited on the east-central section of the Institute grounds. The analog is in daily use and open to the public.

The analog relies on the direct analogy between the equations governing transient flow in gas piping systems and current flow in electrical transmission lines. Based on this analogy, complicated systems of pipe are replaced by assemblages of discrete capacitors, inductors, and resistors. The components are arranged in sections, each representing a piece of pipe, usually a foot in length. Typical piping systems average 1,000 sections of “pipe,” but larger systems can require as many as 4,000 sections.

The analog “pipe” is connected to the compressor analog that alternates the voltage between values representing suction and discharge pressure for the compressor. Check valves are simulated by diodes that act in a manner analogous to mechanical valves.

Dynamic pressure pulsations are displayed in either the time or frequency domain on the operator’s console along with the pressure-volume card for each compressor cylinder, allowing the operator to measure and analyze both pulsation levels and compressor performance. Probes acting as pressure transducers can be attached to any point in the simulated piping system to reveal pulsation levels. The changes in pulsation levels with compressor speed also can be easily studied, and, because the analog operates 1,000 times

Original analog components, including crankshaft power supply, oscillator, instrument console, and piping coils and capacitors, are mounted for permanent display at SwRI.

The current generation hybrid simulator uses the same operational principles as the original analog. The analog facility provides an uninterrupted stream of royalties from users, and it has funded nearly $25 million of research to broaden the understanding of machinery and piping dynamics.

faster than real time, such a speed sweep can be quickly completed without the introduction of distorting transients.

The system continues to provide an innovative way to design piping systems in accelerated real time with an analogy easily understood by piping designers. More than half of the designs are undertaken with active participation by company designers, of whom more than 4,000 have worked with the analog since its inception.

Engineering soundness, effective computational speed, clear user interface, and accuracy have given the SGA analog a continuous 35-year record of service to the energy industry.

Mechanical Specifications

Compressor speed	60 to 2,400 rpm
Size	10 to 15,000 hp
Discharge pressures	25 to 45,000 psi
Pipe diameter	3/8 to 60 inches
Number of cylinders	1 to 10 (double-acting)
Number of stages	1 to 5
Pipe sections	50 to 5,000
System pipe length	10 to 3,000 feet

Technical Background

In the late 1940s and early 1950s, the natural gas industry was faced with growing demands for energy. To meet these demands, many pipeline companies had plans for adding hundreds of thousands of horsepower between existing compressor stations on their pipelines.

Many of the facilities built in this period experienced such severe piping vibration that the surrounding area literally rumbled. The culprits were the high pulses generated by reciprocating compressors. These acoustic waves build up in the piping like resonating organ pipes, having as they do varying lengths, each with its own pitch. When the wave frequencies coincide with the pipes' mechanical resonance, the result is vibration that is potentially harmful to machinery, piping, and personnel.

The need was obvious for an analytical tool that could predict the problem before it occurred in the field. The PCRC organized a joint venture research effort funded by member companies that contracted Southwest Research Institute to find an enduring solution.

Work began on the development of an electrical model to simulate the acoustical properties of complex piping systems, where lengths of pipe were simulated by wire coils, and fluid properties within the pipes by electrical capacitors. The actions of reciprocating compressor cylinders were duplicated with capacitor pumps. By combining capacitor pumps with the other electro-acoustic analogies, a prototype compressor station simulator was created. Pressure was represented by the voltage in the electrical circuits, and current represented mass flow. The capacitor pumps injected voltage pulses into the model just as pressure pulsations are generated at compressor stations. Pulsations at different points in the piping could be measured, and the effects of piping changes could be rapidly evaluated. It was now possible to design piping systems free of damaging pulsations and vibrations.

The analog has been refined since its inception, taking advantage of pertinent technological advances, and today's analogs represent the latest in sophisticated electronics. Six analogs that can be interconnected for large and complex systems are housed in a special laboratory at SwRI, and PCRC-licensed analogs are also located at Cooper Industries, Dresser-Rand, Inc., Enron Gas Pipeline Group, and Peerless Manufacturing Company.

The ASME History and Heritage Program

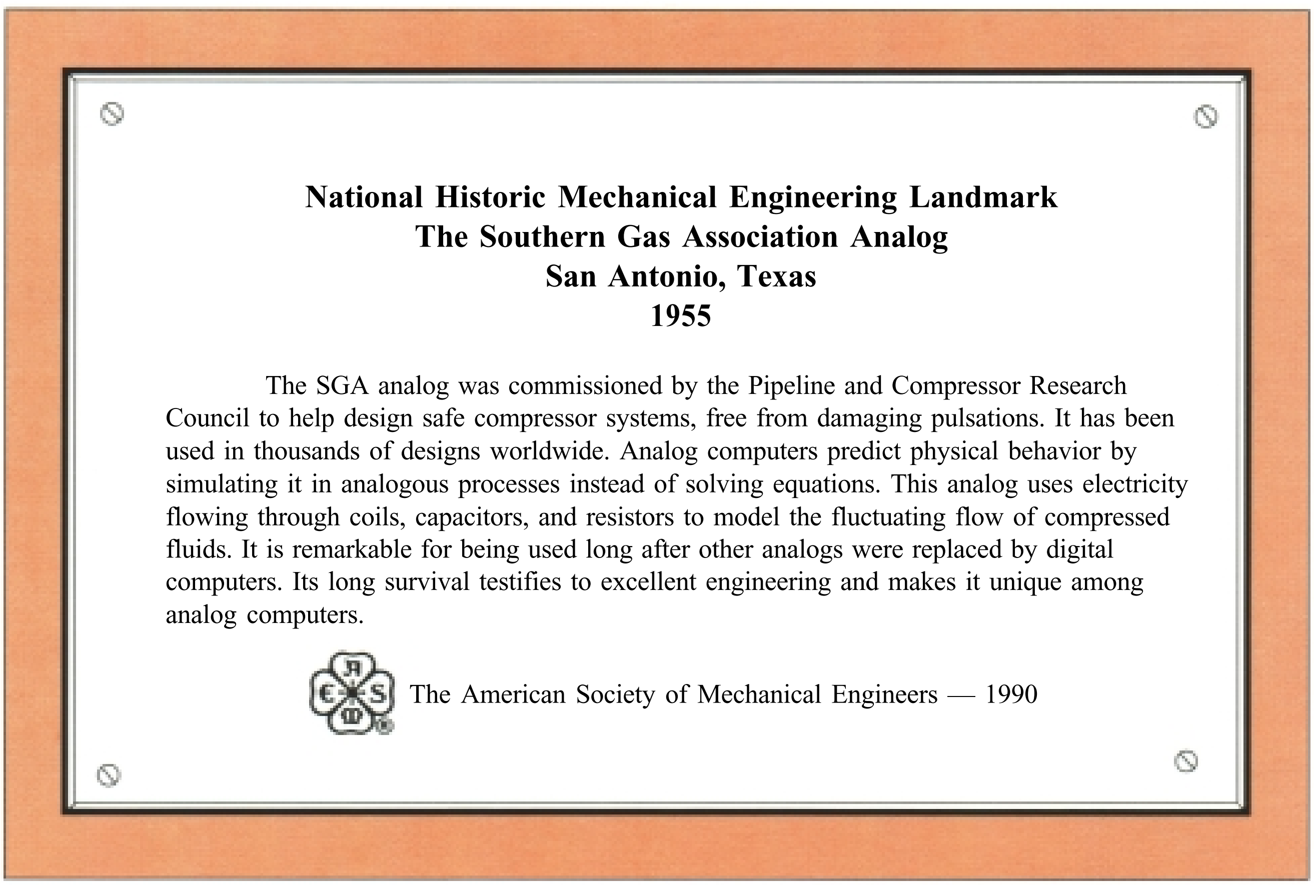
The ASME History and Heritage Recognition Program began in September 1971. To implement and achieve its goals, ASME formed a History and Heritage Committee, initially composed of mechanical engineers, historians of technology, and (*ex officio*) the curator of mechanical engineering at the Smithsonian Institution. The Committee provides a public service by examining, noting, recording, and acknowledging mechanical engineering achievements of particular significance.

The SGA analog is the 97th National Historic Mechanical Engineering Landmark to be designated. Since the ASME Historic Mechanical Engineering Recognition Programs began in 1971, 138 Historic Mechanical Engineering Landmarks, five Mechanical Engineering Heritage Sites, and two Mechanical Engineering Heritage Collections have been recognized. Each reflects its influence on society, either in its immediate locale, nationwide, or throughout the world.

An ASME landmark represents a progressive step in the evolution of mechanical engineering. Site designations note an event or development of clear historical importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The ASME Historic Mechanical Engineering Recognition Program illuminates our technological heritage and serves to encourage the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians, and travelers. It helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

The History and Heritage Committee is part of the ASME Council on Public Affairs and Board on Public Information. For further information, please contact the Public Information Department, American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017,212-705-7740.



Acknowledgments

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