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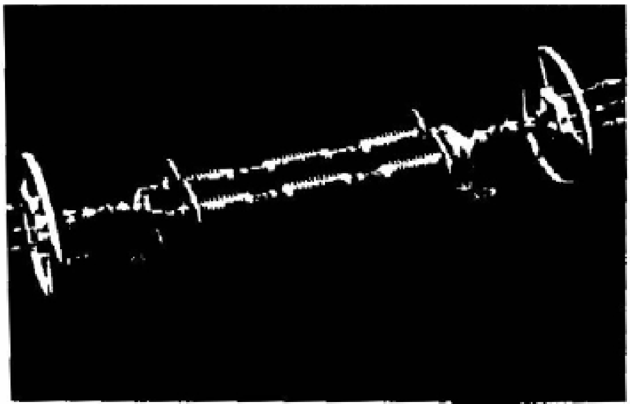

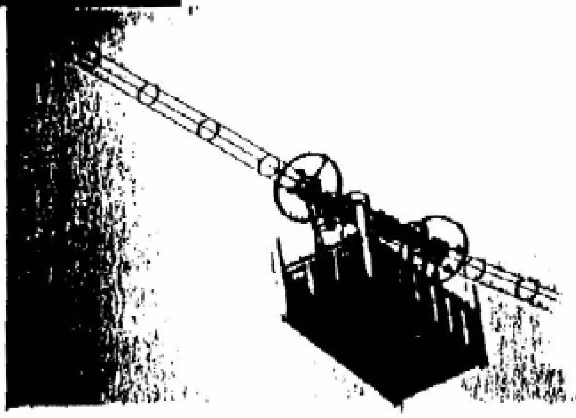

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United States Coast Guard

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Naval Engineers Evaluate Magnetic Boiler Feedwater Treatment as an Alternative to Chemicals.

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Scaling and internal corrosion of boilers are expensive, serious problems which traditionally are treated by adding chemicals to the feedwater which mitigate their deleterious effect on boiler performance. Scale removal is usually accomplished with some type of acid flush, while excessive corrosion usually results in replacement of tubes or other internal components. Treatment and flushing chemicals must be handled as hazardous waste, are dangerous to personnel, often require special stowage aboard ship, and pose a threat to the environment as well as to the internal surfaces of the equipment being treated or flushed. In addition, compliance with chemical treatment Planned Maintenance Schedule (PMS) requirements can cost one to three man-hours per day, and a thorough acid flush may keep a boiler off line for several days.

The effectiveness of chemical treatment in general is questionable as evidenced by the necessity for periodic cleaning of systems that are treated chemically, supposedly to prevent scale formation. Often, corrosion and scaling occur because the personnel monitoring the systems either invoke the adage "if X gallons of chemicals are prescribed, then twice as much will be twice as good," or are habitually in receipt of ancient chemicals through the federal stock system which are often beyond shelf life and thus of questionable value, even if used correctly. Others simply fail to treat the water altogether because there are "more important things to do."

These practices can result in extensive corrosion when strong acids or bases are used for either pH control or cleaning. In addition, strong bases can lead to caustic embrittlement of the waterside. The bottom line though is time. It may take several hours a day to properly monitor boiler feedwater using chemical testing and treatment procedures, especially if you have to sample, test, treat, resample, and retest. This "descretized" type of treatment may leave you with a decent data point for that particular time of the day, but there is little certainty that the water test could be repeated with good results even as little as an hour later.

Magnetic Boiler Feedwater Treatment (MWT) has been in prototype evaluation aboard CGC MELLON since August 1989. All feedwater parameters continue to be within acceptable limits, and periodic waterside inspection of the boilers continue to reveal no internal scale or corrosion. From November 1989 through March 1990, a corroborative evaluation of MWT was done on CGC SHERMAN using the MELLON's devices. Upon completion of the evaluation, SHERMAN returned to chemical treatment until 1992 when the scope of prototype evaluation was expanded to include SHERMAN, three other high endurance cutters (WHECs), and a Polar Class icebreaker.

Graphs depicting MELLON's and SHERMAN's alkalinity and chloride levels during the earlier evaluation period are presented in figures 1-4. Figures 1 and 2 show the steady decline of alkalinity and chlorides following installation of MWT on MELLON's untreated boiler. Within 7-10 days both parameters were averaging within acceptable limits (Alk approx. .1-.5 epm, and C1 > 1 epm). Figures 2 and 4 depict a three phase evaluation on SHERMAN where the boiler feedwater parameters were first stabilized with chemicals. At week four the chemical treatment was secured and the boiler was blown down to remove the chemical laden water. The boilers were run with no treatment until week 16 when MWT was started. As on MELLON, alkalinity and chlorides came back to within acceptable limits and have remained there with absolutely no addition of treatment chemicals. During their respective evaluation periods both cutters were using feedwater sources ranging from evaporator output to the extremely hard, mineral laden water found in Southern California.

MWT is by no means a new concept. The theory was proposed by Michael Faraday in the mid 1800s, and in one form or another, various types of magnetic water treatment devices have been used in industry throughout the world since the late 30's, principally in Russia and Australia. Faraday postulated that a conducting fluid moving through magnetic lines of force would generate an electric current perpendicular to both the fluid flow and the magnetic field. A recently demonstrated corollary to this the magnetohydrodynamic (MHD) propulsion system used on Japan's experimental vessel, YAMATO II. The YAMATO II generates its own magnetic field and electric current with superconducting magnets and powerful generators which force water through its thrusters.

MWT devices on the other hand, place a strong magnetic field in a moving waterstream. The MWT device generates a field which acts as a "stator" and the feed pump provides the energy to move the liquid "armature" through this "stator." Although the absolute difference in potential is small (millivolts), it is sufficient to hold the piping negative with respect to the waterstream for as long as continuity is maintained downstream. Nothing is added to, or removed from the water, but in theory, the manner in which suspended carbonates and water molecules interact with each other and the pipe/tube walls is altered by changing the relative charge of the wall with respect to the water stream. The dipolar water molecules negatively charged oxygen end is repelled by the negatively charged pipe walls, thus reducing its corrosive effect. Scale forming carbonates, also negative, are repelled and remain in suspension until the feedwater becomes supersaturated. At this point they precipitate and form a soft sludge at the bottom of the boiler which is removed via blow-down.

Scale forming carbonates are predominantly a combination of two crystalline forms, aragonite, and calcite. Calcite (principal ingredient of "hard scale") has a much more dense crystalline structure than aragonite. In independent testing documented by the American Society of Corrosion Engineers (ASCE), untreated water precipitated a ratio of calcite to aragonite of approximately 80 percent/20 percent while the ratio measured in magnetically treated water samples was almost the opposite, 30 percent/70 percent. The higher the percentage or aragonite causes the formation of a "soft scale" or sludge. In addition, this serves to demonstrate that altering these particles' crystalline structure can cause their chemical behavior to change.

There are many devices on the market which use electrostatic, electromagnetic, or permanent magnetic systems in an attempt to achieve the aforementioned results. Most were short-lived and unreliable because they were as difficult or more so to maintain then the chemical injection systems they were designed to replace. Electrostatic units, which use high voltage applied to electrodes placed directly in the water steam, are expensive, require the system to be shut down for both installation and maintenance, and can be both a leak source and a shock hazard. Electromagnetic units generally have similar disadvantages, however, some types can be mounted external to the piping. Regardless, both electromagnetic and electrostatic devices require an external source of power, close monitoring, and considerable maintenance (frequent cleaning of the plates or coils). Permanent magnetic systems can be installed either in line with the water flow or mounted externally.

Internally mounted permanent magnetic devices suffer from some of the same disadvantages that electromagnetic or electrostatic ones do; flow restriction and system shutdown to install and service. The externally mounted devices can be installed while the boiler is on line and require little maintenance. Until recently, externally mounted permanent magnetic systems didn't have the ability to project a magnetic field into the water stream of sufficient strength to produce consistent results. The MWT units being evaluated aboard our cutters are externally mounted permanent magnetic devices of sufficient strength to project their magnetic field into the waterstream.

The primary advantage of MWT is its <u>continuous</u> treatment of the water stream, resulting in water chemistry which is virtually constant over time. As with chemical treatment, water testing chemistry is the "measure of merit" of MWT. As long as water chemistry parameters are met, you have done the best you can for your boiler. MWT achieves this consistently high level of water quality, while significantly reducing boiler PMS requirements.

virtually maintenance free and retain their strength indefinitely. In addition, the resulting changes in boiler maintenance procedures will result in significantly reduced PMS man-hours, and preclude the need to purchase treatment and cleaning chemicals. Cutters using water softeners will save even more since softening dock water is unnecessary if MWT is used.

MWT represents a significant shift of status quo in water treatment technology, and for obvious reasons the multi-billion dollar chemical industry is certainly not a strong advocate of it, to say the least. As an environmentally concerned organization, the Coast Guard should leave no stone unturned in evaluating and adopting technology which will reduce our dependence on treatment, cleaning, and testing chemicals as they become increasingly difficult to dispose. As positive as it may sound, MWT should not be approached as a panacea. Systems using this technology remain subject to continued careful monitoring of water chemistry and periodic visual inspections to insure long term effectiveness of the treatment. MWT is simply an alternative to the chemicals presently used for scale and corrosion reduction. G-ENE's expansion of its evaluation of this technology on shipboard boilers will provide a basis from which to make a decision to embrace this technology fleetwide and pursue follow-on applications on distilling plants, heat exchangers, and engine jacket water systems.

ABOUT THE AUTHOR

CDR GREGORY J. MACGARVA is a 1976 graduate of the United States Coast Guard Academy receiving a Bachelor of Science degree in Marine Engineering. Following an initial sea tour aboard USCGC SHERMAN (WHEC-720) he did postgraduate study at the University of Michigan, receiving Master of Science degrees in Mechanical Engineering, Naval Architecture, and Marine Engineering. He then served as Assistant Engineer Officer USCGC POLAR SEA (WAGB-11), followed by four years in Headquarters as SCAMP project officer and then as Acquisition Project officer for the 140' WTGB Class cutters. In 1986 he was assigned to RIO Seattle, where he served as technical assistant to the contracting officer and Chief, Technical Branch. He then was assigned to the PRECOMDET for USCGC MELLON and following her commissioning, served as Engineer Officer. In 1990 he was assigned to the Naval Engineering Division, Coast Guard Headquarters as Chief, Program Standards Branch. He is presently Chief of the Human Resources Policy Section in the Naval Engineering Division Coast Guard Headquarters.

In Summary, Magnetic Boiler Feedwater Treatment:

Eliminates:

- SCALE
- DISCHARGE OF TREATMENT CHEMICALS TO THE ENVIRONMENT
- NEED FOR ACID CLEANING
- EXPOSURE OF PERSONNEL TO TREATMENT AND CLEANING CHEMICALS
- NEED TO PURCHASE, STORE, AND DISPOSE OF HAZARDOUS TREATMENT AND CLEANING CHEMICALS

Reduces:

- WATERSIDE CORROSION RATE
- PMS MAN-HOURS
- MAINTENANCE $

Increases:

- BOILER LIFE
- BOILER EFFICIENCY
- WATERSIDE INSPECTION PERIODICITY

Based on results observed during prototype testing thus far, MWT functions quite effectively in place of boiler water treatment chemicals. During July 1992, several major industrial facilities were visited to corroborate the Coast Guard's experience with Magnetic Water Treatment (MWT) devices presently being prototyped aboard CGC's MELLON and SHERMAN:

Textile Manufacturer – Evaluated MWT on one of their six 750 HP, 100 PSI boilers for approximately one year. Once installed, they insured frequent (about every two months) waterside inspections were made because they were starting from a scaled condition. Daily feedwater test readings fell within an acceptable range in about two weeks and each inspection showed progressively less scale, leading them to install the devices on the other five boilers as well as a 750 ton cooling tower. The site visit was coordinated to coincide with the annual state inspection of boiler used in the prototype evaluation. After nearly three years with only MWT, the waterside had neither scale nor any evidence of corrosion. The company estimates an annual savings in chemical costs of approximately $35K.

Chemical and Pharmaceutical Manufacturer – Has been using MWT exclusively in their three (1 ea: 250 ton, 500 ton, and 750 ton) cooling towers for the past two years. In addition, approximately one year ago they installed MWT on two of their 75HP fire tube boilers. They cited savings of approximately $40K per year in chemical costs at their plant.

Pharmaceutical Manufacturer R & D Complex – three years ago, they were faced with chemical treatment costs that were increasing at a rate of 40-60 percent per year. The Facilities Manager prototyped MWT on one of his 20, 1,000 ton cooling towers and observed a steady reduction in scale, algae, and makeup water consumption. In addition, NALCO Chemical Co. (their source of treatment chemicals) performed a side-by-side corrosion coupon test on a chemically treated cooling tower and the MWT treated one. While the chemically treated tower yielded corrosion rates of 1.8 to 4.5 mils per year, the MWT treated tower showed rates of .1 to .3 mils per year. Based on their experience they purchased enough MWT devices (about 500) to treat every cooling tower on the facility. It was decided to do the cooling towers before the boilers because the treatment chemical costs were more, therefore the payback was quicker. MWT will be installed on their eight 850HP boilers as soon as funds become available. The company estimates savings in chemical costs to be nearly $100K per year thus far.

In summary, findings indicate MWT to be extremely successful in the private sector boiler and cooling tower water treatment applications. Scale is eliminated and corrosion rates are significantly reduced. Visual inspection and discussions with the industry representatives at these sites fully corroborate our own three year prototype testing aboard CGC MELLON. Since chemicals are not employed, MWT precludes the discharge of water treatment chemicals to the environment through blow-down. The need for periodic acid and/or manual cleaning is eliminated. Exposure of personnel to the treatment and cleaning chemicals is avoided, and storage space for chemicals is no longer necessary. Since the units significantly reduce corrosion rates, longer boiler life can be expected. Once installed, the devices are

ALKALINITY/MELLON

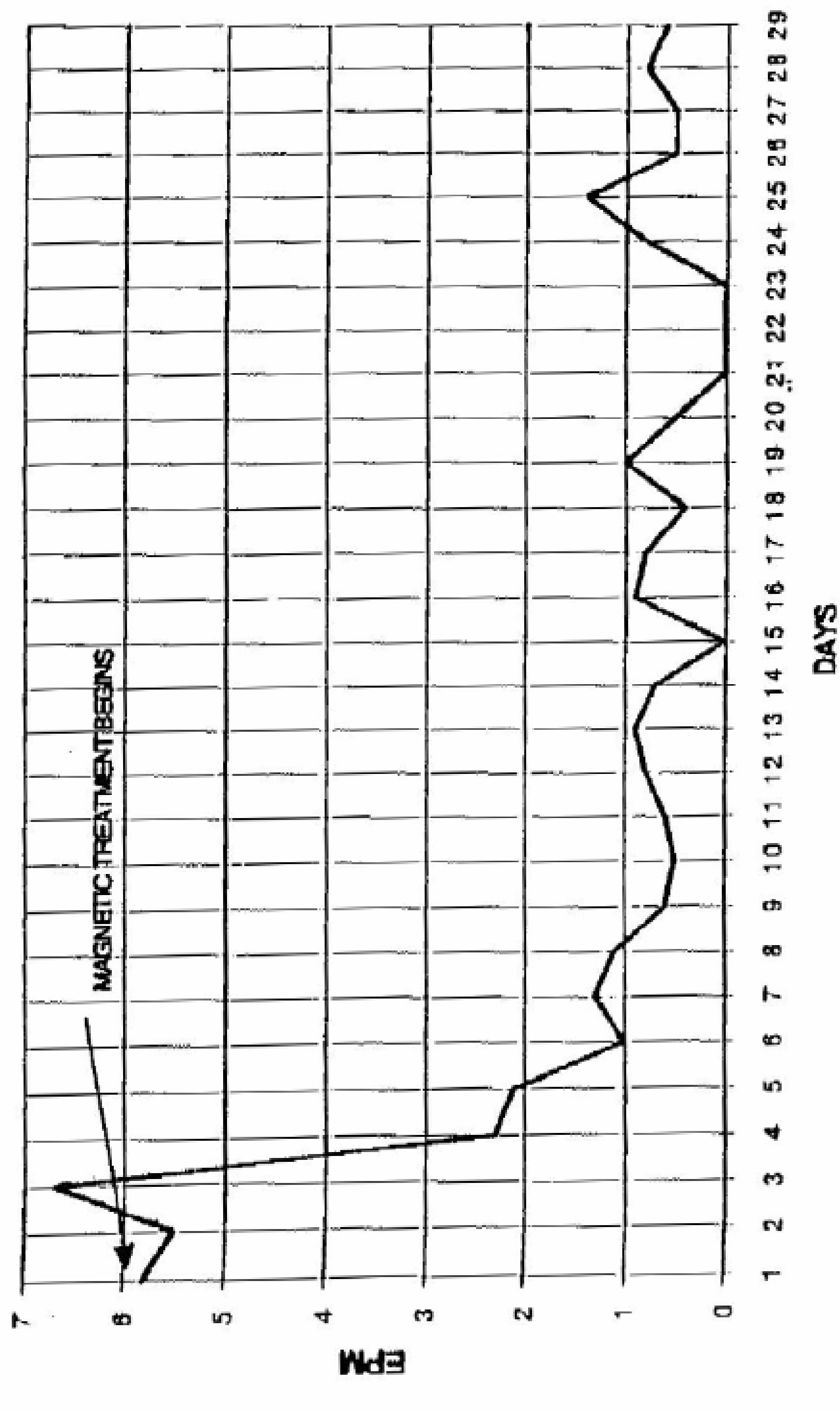

FIGURE 2

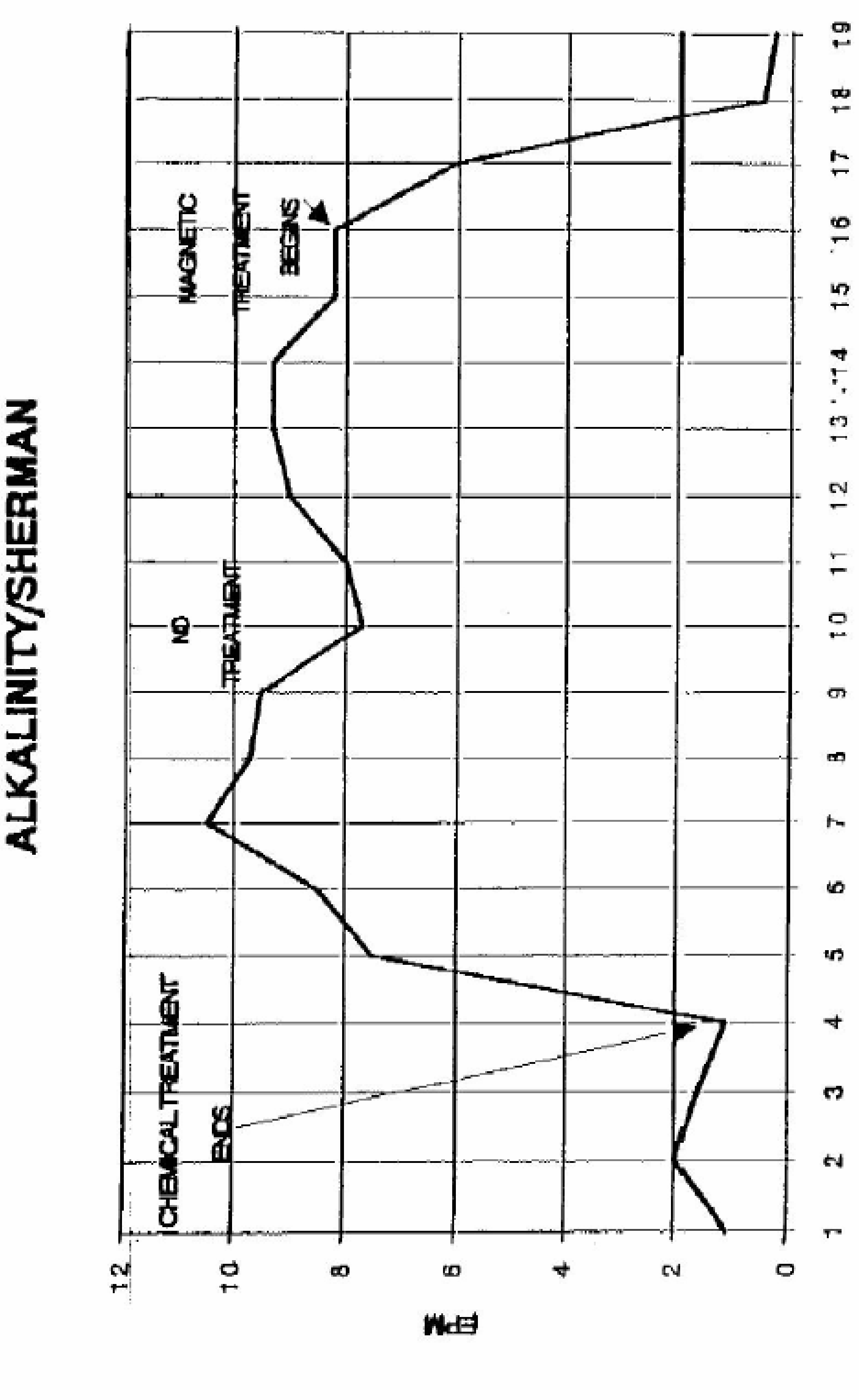
ALKALINITY/SHERMAN
EPM
WEEKS
CHEMICAL TREATMENT
ENDS
NO
TREATMENT
MAGNETIC
TREATMENT
BEGINS
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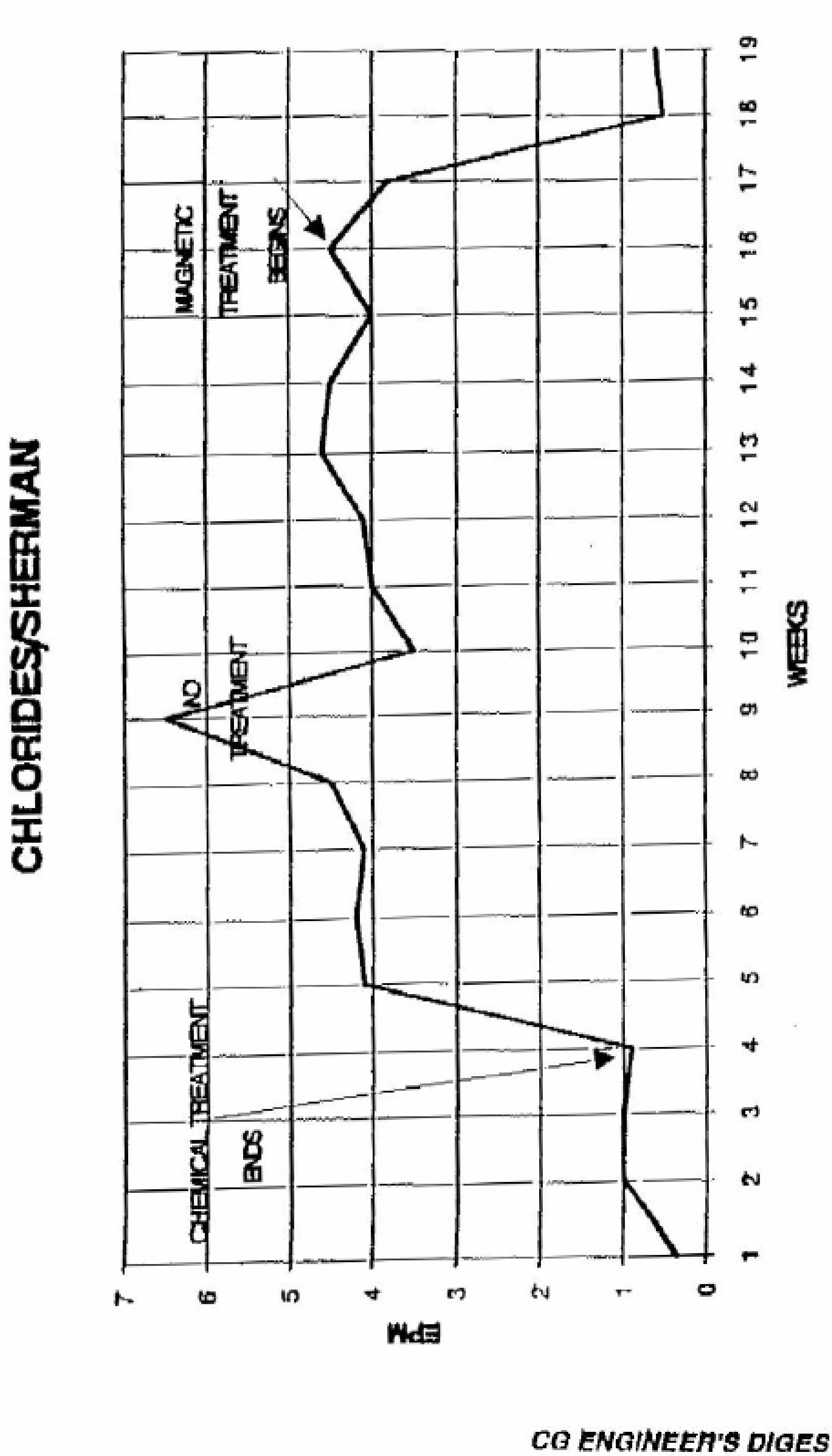
FIGURE 3


CHLORIDES/SHERMAN
EPM
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WEEKS
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CHEMICAL TREATMENT
ENDS
NO
TREATMENT
MAGNETIC
TREATMENT
BEGINS

FIGURE 4