Magnetism and arc blow can cause welding problems when welding pipe particularly for pipelines. This has been extensively documented by a number of studies by people and organizations. The pipeline research committee of the American Gas Association had Proctor Inspection Consultants in Houston, Texas do investigations into this. A paper was published in March 1980 as a result of this work (Reference #1). The explanation of magnetic force, field generation associated with pipeline inspection pigs, geomagnetic fields and magnetic energy are covered in that document. There are various procedures suggested in this paper. Other investigations and analysis have been carried out and a number of the publications are listed in the references. An investigation by Jose Hiram Espina Hernandez and associates discuss the problems with residual magnetism and arc blow which increases the incidents of defects. I quote from their paper regarding arc blow: “Residual magnetism of the parts to be soldered effects DC arc welding of pipelines during repair causing the arc to deviate, a phenomenon known as arc blow. Steel pipelines are huge ferromagnetic structures and can be magnetized by the earth’s magnetic field …” (Reference #2)

There is a wide variety of opinions expressed by others as to the maximum tolerable level of residual magnetism and various ways of measuring this residual magnetism. The National Shipbuilding Research program 1993, held a Ship Production Symposium sponsored by the Hampton Roads Section Society of Naval Architects & Marine Engineers (Reference #3). A System to Control Magnetic Arc Blow in Welding was designed by R. Brian Jones of Newport News Shipbuilding and in their investigations they found very high residual magnetic fields that, in some cases results in a welder not being able to strike an arc. They developed a system to help mitigate this and their device needs to be in position near where the welding is being done. They report that at about 40 gauss that the welding arc can become unstable and in some cases even blown out. In the paper by Jose Hiram Espina Hernandez and associates (Reference #2) they express the opinion that residual magnetism up to 40 gauss could be tolerated if certain procedures that they out line are followed but there is no report on the actual field usage of these proposed procedures. The 40 gauss residual magnetism acceptable level for weld referred to in the literature citied appear to be based on balancing the residual magnetism level in the adjacent pipe ends, but over 40 gauss demagnetizing is still required. Residual magnetism is excess of 40 gauss is not uncommon in pipeline pipe. Figure #1 shows a 24” pipe being prepared for welding. The solid steel pin hanging from the pipe indicates the residual magnetic field that made it impractical to weld and it was demagnetized with 3 pulses of the WDV-25PD Coil. The source of the magnetization was/is unknown and the residual magnetism reported by the operator was 50 gauss, with the gauss meter 2ft from the end of the pipe. This is an unusually high level of residual magnetism, and with no explanation of how this was induced
Causes of Residual Magnetism:

There are many causes of residual magnetism in pipes, such as magnetic fields induced during pipe manufacturing and coating processes. Other factors are handling of pipe using, however transporting of pipes, particularly in and around overhead power lines is reported by operators to be affected to a greater degree. It has been reported by some researchers that the movement of pipe with respect to the earth’s magnetic field can induce residual magnetism in pipes. To our knowledge we are not aware of definitive studies to try to identify and differentiate between the various causes for residual magnetism in pipes. Flow of fluid in pipe and pipelines are reported to magnetize them to a high level. It would be a very complex study to try to deal with the prevention of residual magnetism in pipes and it is not considered a practical approach. Field measurements of pipe, both along construction right of ways and in storage have been made and found that residual magnetism can vary widely. The lowest residual magnetism found in our investigations was in the order of about 2 gauss but we also found residual magnetism in excess of 50 gauss which is well beyond field weld-ability. There are varying opinions as to the maximum allowable residual magnetism for pipe welder’s capability. It has also been found that the level of residual magnetism in pipes that are strung along a right of way vary significantly from pipe to pipe and location to location and around the circumference (Figure #2). It is our conclusion and by others with direct experience with pipe welding that it is not considered practical to prevent the magnetization of pipes in the normal course of pipe manufacturing, coating, handling, stringing etc and the most desirable situation is to be able to demagnetize the pipe ahead of the alignment and welding process. Mr. Ian Kopp (Acknowledgement # 1) and Tim Marten (Acknowledgement #2) feel that the maximum allowable residual magnetism is 5 to 7 gauss to prevent the formation of defects due to arc blow. The experience of Ian Kopp and Tim Marten with cable wrap type of devices for dealing with residual magnetism is that it is time consuming and interferes with pipe welding operations. Further it is problematical
to obtain the desirable maximum level is $5 - 7$ gauss. It can be assumed that the tolerances of pipe ends can be better dealt with by welders, if the pipe ends are demagnetized. The normal variations within specified tolerances, such as land width, inside diameter variations, roundness etc is routinely dealt with by welders. However, residual magnetism makes it much more difficult for the welder.

Hold field indicator face up and rotate 360 degrees to check for residual field strength of pipe.

Residual field strengths of $10$ gauss and up are reason for damaging pipe. The higher the field the harder the piece is to weld. It is recommended to remove residual fields to a $3$ to $5$ gauss but with practice it will be easy to achieve $0$ Gauss.

**Figure #2** Circumference of pipe, Kevin King, Fatigue Masters Inspection

**Figure #3** - 20" pipe, 10 Gauss, 6" from end of pipe on pipeline right of way

**Figure #3** - 20" pipe, 10 Gauss, 6" from end of pipe on pipeline right of way
Measurement of Residual Magnetism:

The most widely known technology for doing this are electronic devices based on the Hall Effect principle (micro measurements). These devices are generally used in various studies that have been published regarding residual magnetism and arc blow. It is often assumed that digital devices are better however, in this application they are more difficult to use. These devices require knowledge and skill to use them effectively. Purpose built analog magnetometers shown in Figures #3 and #4 have been developed to make it far easier and practical to determine the effective residual magnetism under field conditions (macro measurement). These units are readily available in the ranges of 10-0-10, 20-0-20 and 50-0-50 Gauss and are available from several manufacturers. However, it is important that the devices used are linear and calibrated in a uniform field device. Their range can be readily checked in the field with a hand held device (Figure #4) as to whether they are within the range for which they have been calibrated to. Typically, the 10-0-10 or 20-0-20 gauss meters are used to check a pipe end. However, if these analog magnetometers are placed on a pipe end, their internal movement can be damaged by strong magnetic fields, such as during a Reversing and Reducing Demagnetization procedure. These simple Analog Gauss Meter are very effective and only take minutes to train an operator to use these appropriately to obtain consistent and repeatable results. Of course the measurements must be made at the pipe end that has been prepared for welding. These devices are referred to, including their use, in the demagnetization procedure developed by Mr. Kevin King of Fatigue Masters Inspection Ltd (Acknowledgement #3). The electronic HALL Effect Magnetometers are useful for investigative work where they are used by highly trained and experienced technical personnel. Hall Effect magnetic field measurement and their use under actual field operating conditions is difficult and the information provided is also difficult to interpret and are not practical for field use.

Figure #4 10-0-10 Gauss Meter & Verification Fixture
Techniques and Equipment for Demagnetization:

There are various types of demagnetization devices, and these are summarized in T H. Hill associates DS-1, fourth addition volume 3 Drill stem Inspection (Reference #4) procedure. The bulk of this procedure and summary deals with the use of various AC (Alternating Current) devices to deal with residual magnetism. It is a good summary of these devices and techniques but in 3.36.3, under procedures, it states “demagnetization using DC equipment is recommended for larger components as AC fields lack penetration to remove internal residual magnetization and states:

- Starting current amperage will be equal to or greater than the amperage used for magnetizing
- Component is subjected to consecutive steps of reverse and reduced direct current magnetization until the desired level is achieved.
- Each step down must last one second in order to allow the field in the part to reach a steady state.

The T.H. Hill procedure did not anticipate the Western Instruments’ WD-Series of demagnetization equipment. The DC principle that is referred to has been known for a long time however, the equipment and procedures have been difficult to implement in a practical form. Western Instruments WDV coil development makes it possible to effectively demagnetize pipes under field conditions. The pulsed DC current and its control makes it practical to reduce the residual magnetism to near zero (earth’s magnetic field in this area is in the range of ½ gauss). The nature of these DC pulses not only demagnetizes the ends of the pipe, but the ends stay demagnetized, typically for days. Tests on 10 ¾” O.D. pipe were carried out for 10 days using both Analog and Hall Effect Magnetometers with no measurable re-magnetization and this is because the demagnetization process is effective through the full thickness of the pipe wall, without any skin effect as with AC methods.

Figure #5 shows a picture of this device being used on 16” pipe on a pipeline right of way. The procedure for using this is covered in Kevin Kings (Fatigue Masters) procedure which is in Reference #5 and in Acknowledgements #3. An operator can typically be trained in a short time to use the equipment. Kevin King has found that, in practice it is capable of reducing the residual magnetic field in the ends of the pipe in less than a minute. Once operators get experience they can check the end of the pipe with the Analog Magnetometers and can often get the residual magnetism down to the order of 0-3 gauss with only one pulse, which is considered a low enough magnetic field for field welding pipe.
Figure #5 Pictures from the 16-24” line near Gibbons, Alberta
This demagnetization system required the development of unique power system and controls that can operate within the magnetic field of the demagnetization coils and standard coil winding techniques cannot be used in conjunction with these special pulses. However, as operators gain experience it often requires only one pulse to reduce the residual magnetism to an acceptable level of 5 -7 gauss. The shape of the DC pulses is an important factor for the effective demagnetization of the pipe ends and the ends stay demagnetized for an extended period. Therefore it is practical for the pipe strung along the right of way to be demagnetized well ahead of the welding crew. This is confirmed by Mr. Ian Kopp of Surerus (Acknowledgement #1). Mr. Kopp also stated that weld repairs drop by at least 75% when welding demagnetized pipe. The range of coil sizes is shown in Figure #7 and are available to 60” I.D. and each size coil can cover a wide range of pipe sizes.

Metallurgical Factors:
Researchers have published information referring to the effects of metallurgical conditions that can affect welding and their residual magnetic fields. However, the complete demagnetization through the entire thickness of the end of the pipe obviates most metallurgical factors in magnetic materials. There are indications, based on field experience, that lower strength grades of pipe (and lower chemistry) can tolerate
higher residual magnetic field levels, and however, we are not aware of a definitive study of this. Experience with 12” grade B pipe in a tank farm rehabilitation project indicated that such lower grades of pipe may be welded up to a field level of 15 gauss, but with great difficulty. The polarities of adjacent pipe ends are also a factor.

The Bauschinger Effect is not widely understood but very relevant to pipe manufacturing, bending and other operations and this aspect is particularly related to residual stresses that result from manufacturing and bending strains. Bending strain distribution and the effects are discussed in reference #8 and it is a major need in the industry. There is a particular need for spiral welded pipe, where the heat affected zone can reach residual stresses at or near the yield strength. This results in increased sensitivity to stress cracking, particularly in the presence of such compounds as H2S (hydrogen sulfide), which is present in untreated bitumen. An example of this was the abandonment by Shell of spiral welded pipe line in Southern Alberta. This line failed at over bends. There was also a 52 mile, 24” line in British Columbia that had to be abandoned due to repeated failures for sour service. Experimental work conducted, in conjunction with Mr. Lloyd Crumback, the founder of Alberta’s first dedicated pipeline equipment company in their shop in Edmonton and results are in Reference #8. The present field bending equipment results in undesirable tensile strains in the pipe which can and need to be avoided. The high tensile strains have been found to be related to stress corrosion cracking. Figure #8 shows a field bent 42” diameter pipe that was used to develop the techniques and procedures for detecting stress corrosion cracking, and this was conducted by a metallurgist. Tensile strains make steel more susceptible to stress corrosion cracking even at low concentrations of H2S (Hydrogen Sulfide).

![Figure #8 field bent 42” diameter pipe](image-url)
Conclusion:
Increasingly magnetization and demagnetization equipment needs to be “purpose” built to meet the specific conditions that are being increasingly recognized. The development of the pulsed DC coil for down-hole drilling assembly's and field demagnetization of pipe are examples. A 16, custom coil, computer controlled unit to induce a specific magnetization pattern is shown in Figure #9. Such a system can be built to demagnetize a complete pipe in a short time if the need arises.

For pipeline welding, where about 80% of the welding cost is labor and the system described fills this important need and the coils. Demagnetization using the WDV coils reduces the welding time and reduces the incidents of repairs due to defects very significantly.

![Figure #9 - 16 coil, computer controlled magnetization line](image)

Acknowledgements:
1) Ian Kopp, Surerus, Gibbons Alberta
2) Tim Martin, Cross Country Canada, Spruce Grove, Alberta
3) Kevin King, Fatigue Masters Inspection, Nisku, Alberta
4) Lloyd Crumback, Founder Proline Pipe Equipment Inc., Edmonton, Alberta

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6) Prevent Arc Blow when welding article from Metal Forming May 2001

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9) 969458 Canadian Patent Pipe Bending, Issued June 17, 1975, Alexander Palynchuk

Figures:
1) 24” magnetized pipe, Fort McMurray, Alberta
2) Kevin King, Fatigue Masters Inspection circumference of pipe
3) 20” pipe, 10 Gauss, 6” from end of pipe on pipeline right of way
4) Gauss meter and range checking device
5) Pictures from the 16-24” line near Gibbons, Alberta
6) Diagram of the key demagnetization controls
7) Demagnetization Coil sizes from 8” - 44”
8) 16 coil, computer controlled magnetization line