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News in maintenance of technical state of the main pipelines

Wiadomości z zakresu utrzymania stanu technicznego rurociągów głównych

ABSTRACT

Long-term accident-free operation of the main pipelines depends on monitoring of their technical state, level of their maintenance, realization of physical methods of their diagnostics. Currently used types of main pipeline marking system, which should be replaced with individual bar and QR codes, are considered. This allows combining the information capabilities of various diagnostic systems, repairs and examinations, maintain an individual history of each pipe and monitor pipe operation with allowable defects for underground pipelines.

Keywords: *Pipeline degradation, pipeline diagnostics, pipeline marking system, code plate, bar code panel, low-frequency ultrasonic, magnetic diagnostic, polarization potential, marker pipe*

STRESZCZENIE

Długoterminowa bezawaryjna praca głównych rurociągów zależy od monitorowania ich stanu technicznego, poziomu ich utrzymania i prowadzenia fizycznych metod diagnostyki. Rozpatrzono obecnie stosowane rodzaje oznaczeń głównych rurociągów, które należy zastąpić indywidualnymi kodami paskowymi i kodami QR. Umożliwia to łączenie informacji o różnych systemach diagnostycznych, naprawach i badaniach oraz utrzymywanie indywidualnej historii każdej rury i monitorowanie pracy rurociągu z dopuszczalnymi defektami dla podziemnych rurociągów.

Słowa kluczowe: *Degradacja rurociągów, diagnostyka rurociągów, systemy oznaczeń rurociągów*

1. Introduction

Pipelines consist of various pipe. This difference starts from on-reception inspection of metal sheet, which is used for pipe formation, present production defects and performance of welds in the pipeline. All this allowable defects are present in each pipe in various amounts.

The factors, limiting a period of operation of underground pipelines, are propagating multiple initial defects as well as processes of stress-corrosion, material degradation, fatigue and electrochemical processes. Therefore, regular diagnostics, productive organization of pipe monitoring are the main activities on maintenance of working capacity of specific pipes of underground main pipelines.

Number of defects, detected only at in-line diagnostics of linear parts of the pipelines can make hundreds per 1 km. Their simultaneous removal is very labor-consuming tasks and unpractical. However, the zones with defects should be monitored. Current methods of calculation of limiting state of pipe structures with thinning, cracks, measured geometry anomalies allow high reliability prediction of their residual strength, determination of defects of critical size (requiring immediate removal) or medium (do not requiring immediate removal). Accuracy of such calculations depends on peculiarities of specific part, age and resistance to different types of fracture. Therefore, it is necessary to give preliminary evaluation to all found defects and determine sequence of their removal. A level of danger in the world's practice is marked by color. Pipes with defects can have three colors, namely red, orange and grey. This method can be used for ranking defective zones and attracting attention of services and specialists engaged in pipeline operation. These colors should be indicated on markers of defective zones, pipeline fixture elements, structures subjected to repair and markers provided by process documentation.

In the case of postpone of repair of found defects' the color indications will help to find these zones for their monitoring with some frequency. Besides, in addition to defectiveness problem, all pipes (stalks, sections) should have own codes (numbers), being brought to the surface and read with in-line and manual flaw detectors. Such rules should be embedded in technical documents. These innovations are necessary for safety of the main pipelines being built and reconstructed.

It is well known fact that external pipelines have longer life than underground pipelines. Famous Alyaskinskii oil pipeline, which pumps aggressive oil, has been under operation for more than 60 years and will be used for many years more. Service life of underground oil-and-gas main pipelines can be approximated to time of existence of ground pipelines under conditions of equal maintenance of each pipe in the pipeline. For this, they should have own numbers and maximum information about them should be brought to line surface. Pipe state can be easily examined without significant damages and mechanical loads.

Various types of diagnostics are used for underground main oil-and-gas pipelines. Their number continuously increases. The most common among them are:

- in-line [1,7] magnetic (acoustic);
- low-frequency [2] ultrasonic (guided wave);
- electrometric [3, 4] of insulation;
- coercive-metric;
- magnetometer [5] based on magnetic memory;
- acoustic emission;
- thermographic [2, 7], visual-optical etc.

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DOI: 10.26357/BNiD.2018.011

Each of these 8 types of tests provides its specific information on underground pipelines, which is only considered by repairmen after it has been confirmed through excavation and manual flaw detection means. For this test boring and opening of one or several pipes are carried out. Currently, application of the defectorgams from each of the mentioned types of diagnostics do not allow indicating a pipe having dangerous defects, since these underground pipes are anonymous, i.e. do not have their own numbers (codes). This uncertainty provokes a lot of problems including reduction of pipeline safety.

All mentioned above physical methods of technical diagnostics have their own origin points and coordinate measurement instruments, rules and means of connection of their results mainly to line surface, but not pipe body. GPS space navigation systems are often used fir this. Therefore, it is difficult to compare the results of different types of diagnostics, which should complement each other. The first (overrun, unnecessary rejection) and the second (shortage, flaw detection skipping) types of errors are very significant for each type of test in comparison of the results of each diagnostics type. The repair services have the most problems with the anonymous pipes. We are going to describe some types of diagnostics, the results of which can be clarified and combined by pipe numeration that allows following life time of each pipe.

Figure 1 shows a scheme for monitoring an insulation condition by measurement of pipeline polarization potential [3, 4]. It is used to study the influence of aggressive ground environment, which leads to insulation and pipeline metal failure. Anti-corrosion protection is used for metal protection and it is periodically checked. Insulating coating and cathodic polarization protect the underground pipelines from corrosion. The main criterion of isolation condition [3, 4] is the difference of potentials between metal and medium, called a polarization potential. The potential should be controlled and maintained within a certain range in electrically conductive medium, avoiding the errors of the first and second type. Special, accurate electron devices are used for that.

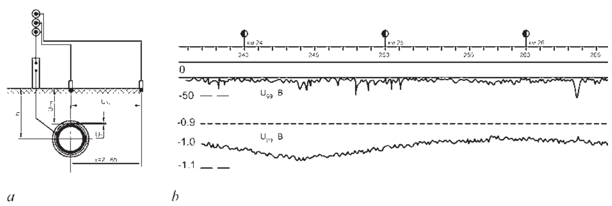


Fig. 1. Evaluation of quality of pipeline insulation based on results of measurement of polarization potential Up: a – scheme; b – measurement results, Umg – potential between pipe and electrode, Ugg – the same at x distance from axis, h – pipeline burial depth

Rys. 1. Ocena jakości izolacji rurociągów na podstawie wyników pomiaru potencjału polaryzacji Up: a - schemat; b - wyniki pomiarów, Umg - potencjał między rurą a elektrodą, Ugg - potencjał jw. w x odległości od osi, h - głębokość umiejscowienia rurociągu

Such an inspection of underground pipelines by electrometric methods (electrodes) from land surface can be contact (Figure 1) and non-contact. The latter significantly increases the efficiency, but do not provide reliable information. There are many original solutions in this type of diagnostics. Figure 1 shows a simplified scheme for measurement of the polarization potential [3, 4]. It presents a measurement point, an electrode buried in the ground at every 5 to 15 meters along pipeline axis and additional electrode, moved parallel to axis at (2-6) h distance. Such a configuration of the measurement point for tens and hundreds of meters along the route allows obtaining distribution of “pipe-to-ground” transient resistance, insulation resistance, “ground-ground” potential distribution and Up - polarization potential along the pipe, assess of the pipeline insulation condition and necessity in its opening and repair.

Figures 2, 3 and 4 show the examples of realization of magnetometric [5] and low-frequency [2, 13] ultrasound diagnostics. Each of these types of tests, as well as in-line diagnostics [1, 7, 11], is realized with the help of special flaw detectors. Their authors try to connect the obtained results to the pipeline body through their own auxiliary means, their origin points, and so on. The magnetometric method (Figure 2) determines the stress concentration zones. These areas with full insulation can contain metal thinning and other defects [5]. In this case magnetogram as well as the results of measurement of the polarization potential are not refereed to specific pipes.

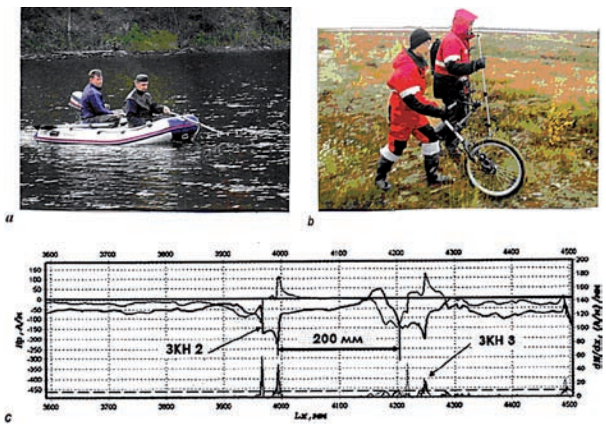


Fig. 2. Magnetometric diagnostics determining stress concentration zones (scz): a, b – measurement process; c – surface distribution H (A/m) of magnetic field intensity and its gradient dH/dx along main pipe axis

Rys. 2. Diagnostyka magnetometryczna wyznaczająca strefy koncentracji naprężeń (scz): a, b - proces pomiarowy; c - rozkład powierzchni H (A / m) natężenia pola magnetycznego i jego gradient dH/dx wzdłuż osi głównej rury

Figure 3 shows an example of diagnostics of main pipeline using low-frequency (LF) [2, 13] ultrasonic testing (UT). In this case, measurements and origin of coordinates takes place from location of a circular antenna on pipe body. This is already somehow more specific point of origin of examined object body. The method of low-frequency ultrasonic testing (LF UT) on new pipelines can provide information on quality of large number of circular assembly joints in the main pipeline of several kilometers. It is necessary to do before pipeline is buried. Wear of pipeline structure can be evaluated on length of penetration of LF-oscillations in metal. Long-range LF UT is successfully used for diagnostics of various pipelines, including the Alaska oil pipeline.

Work [13] describes an interesting experience of application of LF UT, where this method was used for diagnostics of 74 km of technological pipelines. LF UT helped to find 1345 defects with more than 20% pipe wall thinning. Size of thinning was specified by ultrasonic thickness gauges. At that, 263 unallowable defects with wall thickness less than the reject level and 230 defects with wall thickness close to the reject value (plus 0.5 mm) were identified. The first (263) were subjected to immediate repair, the second group (230) was referred to the nearest scheduled repair. The rest of damaged places 1345 - 263 - 230 = 852 (more than 20% of thickness) should be monitored i.e. should be periodically found in the lines and tested. Obviously, that numeration of the pipes can help to find each of 852 + 230 = 1082 places in the pipelines. It is already done for external lines. Let's show how to do this for underground pipelines. Numeration of the pipes is particularly important for underground pipelines, which are out of direct contact of the line inspectors.

Fig. 3. Low-frequency ultrasonic diagnostics
Rys. 3. Diagnostyka ultradźwiękowa o niskiej częstotliwości

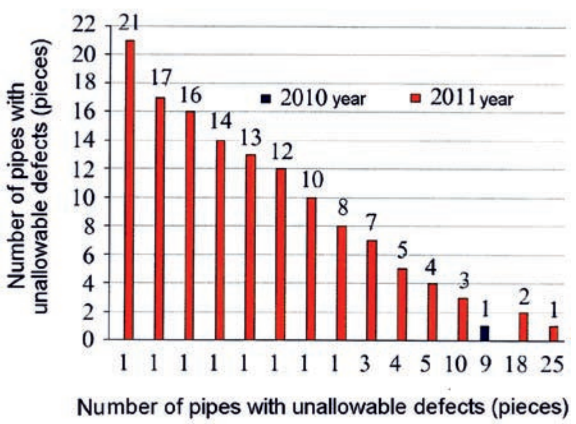


Fig. 4. Diagram of distribution of unallowable detects, pc/pipeline (9 pcs. – 2010, 263 pcs. - 2011)
Rys. 4. Schemat rozmieszczenia niedopuszczalnych defektów, pc / pipeline (9 szt. - 2010, 263 szt. - 2011)

Figure 4 shows [13] a diagram (2011) of pipe-by-pipe distribution of unallowable defects. In this case some pipes have up to 21 unallowable defects. 7 unallowable defects were found in three pipes, and one in 25 pipes. It is characteristic that last year (2010) this company did not use LF UT method and found only 9 pipes with unallowable defects in 74.2 km of pipelines, whereas according to data of 2011 these pipelines had a lot of defects. Reporting for both external and underground pipelines should be made strictly pipe-by-pipe (Figure 4). Pipe-by-pipe record of state is the main peculiarity of ground pipelines in contrast to underground pipelines. Therefore, they have longer life than underground ones. Introduction of numeration, record of real state of each pipe will extend service life of the underground pipelines. At that, each type of diagnostics and repairs receives the possibility to provide the results connected with external (surface) attributes of the line as well as a specific pipe. Then separate types of diagnostics will complement each other, and repairmen will not pay for existing uncertainty. For example, the diagnostics indicates dangerous defects, but manual NDT does not find them because wrong part of the pipeline was opened. Thus, it is nothing to repair. This problem is absent in ground pipelines. The reason of this problem is that the pipes are anonymous.

All enumerated types of diagnostics provide their own important data on the peculiarities of line local places. Not all places identified by that or another type diagnostics are intolerable for further operation. At the same time this zone for another type of diagnosis can be critical, unacceptable for further operation without repair. Therefore, it is important to compare the results of different diagnostics. All numerous types of line state observation can be compared with each other if they have unified system of coordinates, namely pipeline with numerated pipes (assembly welds), each of which has its own history of aging, repairs and defect development. This information should be known to line inspectors, who should easily find location of special pipes.

In-line inspection is the most expensive among all listed types of diagnostics. In-line flaw detectors are continuously improved, the volumes of information provided by them are rising. Inhomogeneities, thinning and other deviations from the standard after defectograms decoding should be found and discussed for a specific pipe following the recommendations of the diagnosticians. In present time a necessary pipe is selected by indirect signs, for example, by the distance from a certain reference mark, which is visualized on the defectogram and can be easily found on line surface. The distance from the reference mark to the pipe, location of test boring place can make hundreds of meters. Therefore, error possibility in determination of excavation point is very high. Old pipelines, except for «nothing to repair" problem, have more dangerous problem, namely "excessiveness". It happens when manual flaw detection finds more flaws than in-line flaw detector. At the same time, something was repaired, but not the most dangerous place, which had not been excavated. Therefore, it is necessary to open large sections of line due to pipes anonymity and uncertainty.

Taking into account these and other reasons, a pipe coding (numeration) system, being well readable on defectogram and by manual devices, should be used for pipeline reconstruction. Today, various indirect systems [9, 10, 11] are used for main line marking. They are based on application of marker plates, reference marks, specially marked tubes (Figure 6) etc. located on pipe body. Markers on pipe body do not completely cover all uncertainties and discussions mentioned above.

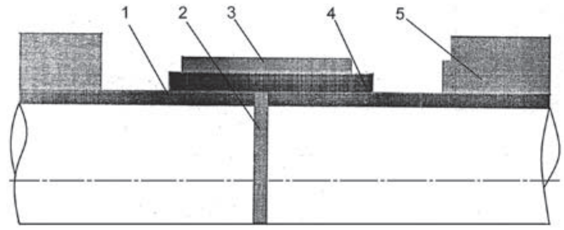


Fig. 5. Location of marker plates in pipeline: 1 – pipe wall; 2 – circumferential assembly weld; 3 – yoke; 4 – marker plate; 5 – concrete

Rys. 5. Lokalizacja tabliczek znamionowych rurociągu: 1 - ściana rury; 2 - obwodowa spoina montażowa; 3 - jarzmo; 4 - tabliczka znacznikowa; 5 - beton

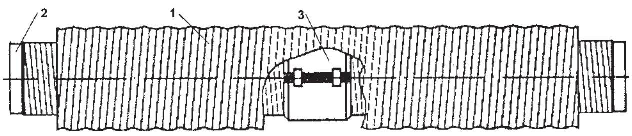


Fig. 6. Marker pipe: 1 – ballast coating; 2 – pipe body; 3 – marker KD 13229.00.000

Rys. 6. Rura znacznika: 1 - powłoka balastowa; 2 - korpus rury; 3 - marker KD 13229.00.000

Work [11] describes marking employing cover marker plates (Figure 5), being located along pipeline on butt joints of separate pipes and corresponding reference marks on line surface. The latest achievement in this series of marks is the marking [11] based on marker tubes, which can be distinguished on defectogram (Fig. 6). They are manufactured under plant conditions and located in line during every 1 - 2 km. It is necessary to read off the long distances moving along the line surface from the reference mark to the marker pipe in order to find a defective pipe. Transfer of information about defect location from the defectogram, which does not take into account peculiarities of line surface relief, is complicated. This is one of the reasons of errors at transfer of the information about defect surface location for determination of excavation place. All detected defects should be found, most of them can be easily identified on line surface at available pipe numeration. .

The code bands (Figure 7), located in a zone of circular assembly weld, can be used as bar code elements in the simplest case, for example, for small diameter pipes. For larger diameter pipes, the bar code can be in a form of panel with code elements (Figure 8) or plate with code holes (Figures 9-13). Thus, there are three constructive possibilities of pipe code formation. A code (number) can be formed for each assembly weld from a specific combination of code elements. These can be bands, panel code elements or holes in a plate. Each of these systems has its own characteristics for manufacture, reading and receiving volumes of information.

The advantage of bar codes based on marker bands lies in suitability for any diameter, their complete identification by in-line flaw detector, since the code bands is a noticeable thickening of metal along the whole pipe generatrix. Such a code is impossible to miss.

Markers bands (Figure 7), located in a zone of assembly weld before insulation, are made of elements of tube metal and tightly abut on pipe surface. They can be multi-element or strip.

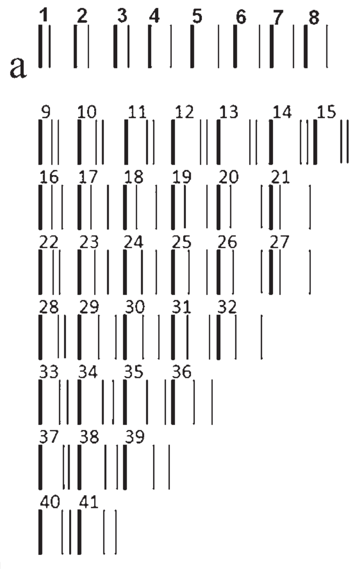


Fig. 7. Formation of bar code due to removal of one (a)or two (b) bands (thin line) from assembly welds (thick line)

Rys. 7. Tworzenie kodu kreskowego w wyniku usunięcia jednego (a) lub dwóch (b) pasm (cienka linia) ze spoin montażowych (gruba linia)

A form, structure of band elements, its distance to assembly weld, and distance between separate elements of the bands (Figure 8) can also be used as informative characteristic of the barcode. These characteristics can be used for identification of hundreds of joints.

If such a bar code is made only at every five joint, i.e. every 4 pipes, then only 20 joints should be marked for a section of 100 pipes.

Figure 7a shows positioning of an isolated strip band near assembly weld (a.w.) at different distances. In this case 8 assembly welds, outlined in Figure with bold lines, were marked in such a way. A thin line is a strip or composite code band, located to the right of a.w. A set of bar codes can be formed by positioning of similar bands also to the left of a.w., i.e. in the direction or against the direction of transported product movement.

Figure 7b represents marking of a.w. similar to marking of Figure 7a, but with the help of two bands. The number of markers is significantly increased in this case due to the distance between bands and a.w. 33 of them are shown in Figure 7b, and total number of bar codes in Figure 7 makes 41. One-strip and two-strip bands from Figure 7 lie on the right of a.w. They can also be located in the same way to the left of a.w. Then the total number of bar codes increases to 82. This at 12 m pipe length allows marking each pipe of 984 m line. Multilink complex bands provide much more possibilities for bar code formation in comparison with strip bands. Only two characteristics are examined in Figure 7, namely amount (2) and distance. Additionally, if structural design of barcodes (Figure 8) are taken into account, then the number of codes will grow by an order of magnitude.

Formation of barcodes should be described in technical documentation, where codes and pipe numbers (a.w.) corresponding to each other should be indicated in form of tables similar to Table. No. 1, made for a QR code with two holes of 15 possible.

Bar code panels are recommended (Figure 8) for large diameter pipes. In them short straight code elements are similar to the bands.

Let's calculate how many variants of the bar code can be obtained with 5 and 10 variants of the elements' structures, which can be located close to a.w. or at some distance (2 indications). Marker elements (bands) can be located before a.w. or after a.w. (2 indications).

Thus, 5 variants of element structures (bands) will have 9 distinctive variable indications, and that for 10 variants of such indications will make 14. Let's calculate number of combinations (number of codes) for these cases: $A_9^3 = 9 \cdot 8 \cdot 7 = 504$, $A_{14}^3 = 14 \cdot 13 \cdot 12 = 2184$. In this case all pipe at approximately 5 and 22 km of the line will be able to have own unique codes.

Well-known formula $A_m^n = m(m-1)(m-2)...[m-(n-1)]$, where number of locations equals product of n consequent whole numbers, from which m is the largest.

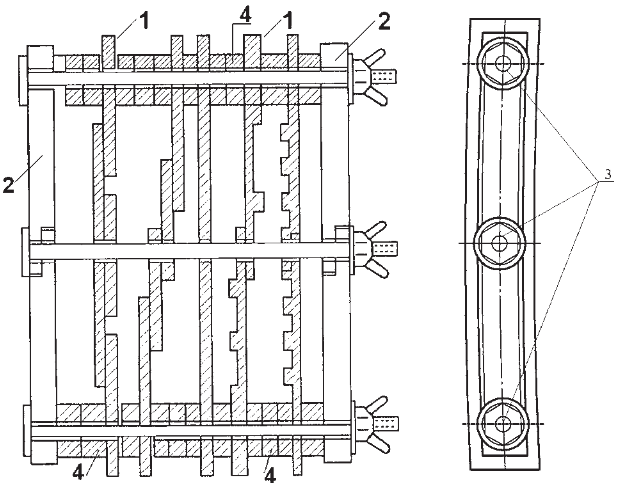


Fig. 8. Bar code panel consisting of 5 different code elements, combination of which determines pipe number: 1 – code elements; 2 – cheek, 3- strengthening pins

Rys. 8. Panel kodów kreskowych składający się z 5 różnych elementów kodu, z których kombinacja określa numer rury: 1 - elementy kodu; 2 – panel czołowy, 3 szpilki wzmacniające

For large diameter pipes, the bar codes can be made in the form of code panels consisting of short code elements of different geometries. Figure 8 shows an example of such a code panel consisting of five code elements.

The panel in Figure 8 represents a set of code elements assembled on pins with plugs determining the distance between bar code elements. Variation of the set, structure of elements and distance between them forms the codes similar to bar codes from bands shown in Figure 7. A numeration system can start with use of one element, then two or three of the same type, further - different bar code elements. The code panel is located in a near-weld zone of assembly weld before its insulation.

The bar code panel in Figure 8 consists of a set of code elements and auxiliary parts, namely two jaws, plugs and three strengthening pins. The latter, in order not to be visible on the defectogram, should be made of non-ferromagnetic metal, have thickness, diameters and other sizes smaller than the size of the bar code elements. Under these conditions the defectogram will show only the bar code elements without auxiliary parts.

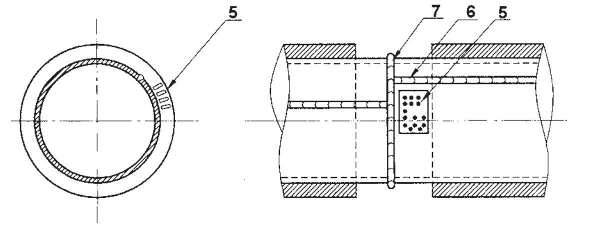


Fig. 9. Position of code panel (5) in zone of intersection of longitudinal (6) and assembly (7) welds

Rys. 9. Położenie panelu kodującego (5) w strefie przecięcia spoin wzdłużnych (6) i montażowych (7)

Each group of information and code elements should follow the applicability hierarchy taking into account their readability on the defectogram. If readability of bar codes depends on direction of magnetization, it has no influence on detection of QR codes. Let's consider the possibilities of QR codes.

Figure 9 shows location of QR code plate 1 in the intersection of circular assembly 3 and longitudinal welds 4. There can be a lot of options for QR codes, their design and meaningful filling. Let's describe four fundamentally different systems for development of QR code designations. They all suggest presence of ferromagnetic plate with holes located on the pipe body.

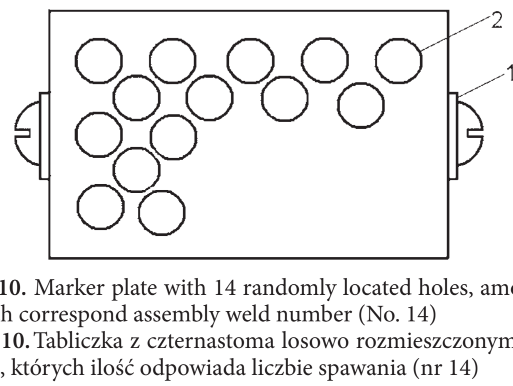


Fig. 10. Marker plate with 14 randomly located holes, amount of which correspond assembly weld number (No. 14)

Rys. 10. Tabliczka z czternastoma losowo rozmieszczonymi otworami, których ilość odpowiada liczbie spawania (nr 14)

Formation of bar code panels in Figure 8 and their assembly on site requires some intellectual efforts. It is much easier to produce and read QR code panels (plates) with holes (Figures 10 - 13). The simplest QR code (Figure 10) is when amount of holes in the plate equals the number without any combinations. Holes' amount corresponds to actual number. This is the simplest possibility of numeration (Figure 10). A more complex variant is to write a code number using the holes as shown in Figure 11. If the holes in Figure 10 plate can be made in random order, then Figure 11 marker plate shows the code number that belongs to pipe number 9175. A lot of holes is necessary in the first (Figure 10) and in the second (Figure 11) variants.

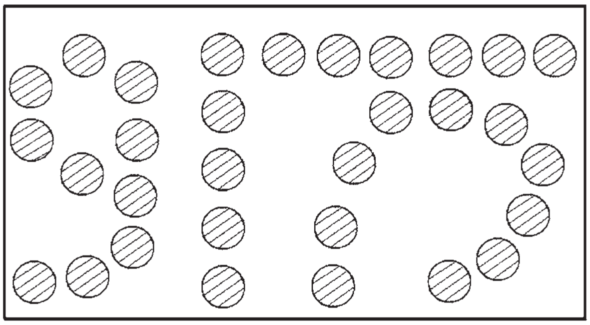


Fig. 11. Marker plate containing 55 points with fixed amount form 31 holes for pipe No. 9175
Rys. 11. Płytka znacznikowa zawierająca ustaloną liczbę możliwych 55 punktów z 31 otworami dla rury nr 9175

In this paper we want to show that even 2 - 3 holes made in the plates allow creating a huge amount of the codes (Figures 12 - 13). Multiplicity of QR codes is reached due to combination of several openings relative to determined points of their possible location.

Figure 12 shows a small plate including 15 determined points, which can have open holes. Opening of one hole in the determined point of such a plate allows getting 15 designations and opening of two similar holes provides 105 designations, as shown in Table 1. If, holes in this code plate have their own distinctive features, for example, one of the two holes has a different diameter, then amount of such codes is doubled and equals 210.

$N = A_m^n = m(m-1)... = A_{15}^2 = 210$ formula is used in order to calculate total amount of variants from 15 with two. In this case each plate has two different holes.

If both holes have the same diameter, i.e. do not have own peculiarities, then amount of codes reduces two times and equals $N = A_n^m/n - 105$. They are given in Table 1. For example, holes number four and twelve should be opened on the code panel for designation of a.w. with number 47, according to Table 1.

Figure 13 shows the code plate which is two times larger than that in Figure 12. It has two times more (30) determined points for the holes than in the plate of Figure 12. Moreover, the holes can be of different and equal diameters. If only one hole of similar diameter is opened in such a plate, then $N_1^1 = 30$ a.w. can be designated, and if two holes (Figure 13b) of the same diameter are opened, then the number of codes will equal $N = A_{30}^2 = 435$. If two holes of different diameters are opened, then $N_{30}^2 = A_{30}^2 = 870$. If three holes (Fig. 13c) of different diameters are opened in the same way, then amount of codes will equal $N_{30}^3 = 24360$. It is already too much. Thus, it is possible to mark all the pipes in the line of 24.360 x 12 = 292.320 m ≈ 300 km length. Redundancy of possibilities is desirable to decrease, for example, by making only one diameter holes in order to facilitate understanding of QR codes application. Then $N_1 = 30$; $N_2 = 435$; $N_3 = 8120$ (~ 97 km).

Tab. 1. Correspondence of QR code to pipe number in form of two similar holes on plate with 15 possible points for holes
Tab. 1. Zależność kodu QR od numeru rury w postaci dwóch podobnych otworów na płycie z 15 możliwymi punktami na otwory

No a.w.	ø n_1-n_2	No a.w.	ø n_1-n_2	No a.w.	ø n_1-n_2	No a.w.	ø n_1-n_2	No a.w.	ø n_1-n_2	No a.w.	ø n_1-n_2	No a.w.	ø n_1-n_2
1.	1-2	17.	2-5	33.	3-9	49.	4-14	65.	6-11	81.	8-12	97.	11-13
2.	1-3	18.	2-6	34.	3-10	50.	4-15	66.	6-12	82.	8-13	98.	11-14
3.	1-4	19.	2-7	35.	3-11	51.	5-6	67.	6-13	83.	8-14	99.	11-15
4.	1-5	20.	2-8	36.	3-12	52.	5-7	68.	6-14	84.	8-15	100.	12-13
5.	1-6	21.	2-9	37.	3-13	53.	5-8	69.	6-15	85.	9-10	101.	12-14
6.	1-7	22.	2-10	38.	3-14	54.	5-9	70.	7-8	86.	9-11	102.	12-15
7.	1-8	23.	2-11	39.	3-15	55.	5-10	71.	7-9	87.	9-12	103.	13-14
8.	1-9	24.	2-12	40.	4-5	56.	5-11	72.	7-10	88.	9-13	104.	13-15
9.	1-10	25.	2-13	41.	4-6	57.	5-12	73.	7-11	89.	9-14	105.	14-15
10.	1-11	26.	2-14	42.	4-7	58.	5-13	74.	7-12	90.	9-15		
11.	1-12	27.	2-15	43.	4-8	59.	5-14	75.	7-13	91.	10-11		
12.	1-13	28.	3-4	44.	4-9	60.	5-15	76.	7-14	92.	10-12		
13.	1-14	29.	3-5	45.	4-10	61.	6-7	77.	7-15	93.	10-13		
14.	1-15	30.	3-6	46.	4-11	62.	6-8	78.	8-9	94.	10-14		
15.	2-3	31.	3-7	47.	4-12	63.	6-9	79.	8-10	95.	10-15		
16.	2-4	32.	3-8	48.	4-13	64.	6-10	80.	8-11	96.	11-12		

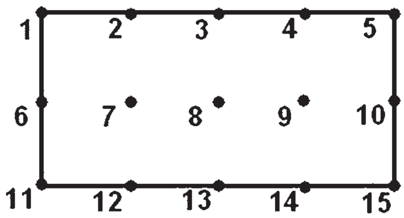


Fig. 12. Code plate with 15 possible holes for 105 and 210 QR codes
Rys. 12. Tabliczka z 15 możliwymi otworami na 105 i 210 kodów QR

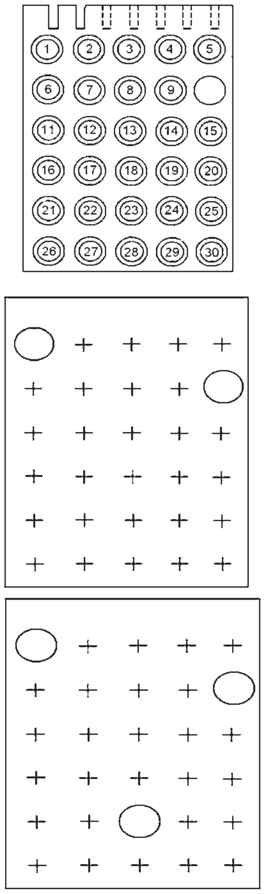
Simple auxiliary capabilities can add necessary information. For example, it can be done by making notches on upper edge of code plate (Figure 13a) or varying determined location of the code, which is also easily determined distinctive feature.

Thus, the simplest from these three considered systems are QR codes based on holes in code plate, namely:

1) holes in random order (Figure 10b), amount of which determines the number;
2) digital image (fig. 11) in form of Arabic (1, 2, 3. ...) or Roman (I, II, III, ...) numbers;
3) combinations of 2 or 3 holes (Fig. 13b, 13c);
4) using one code hole, location of which determines the number (Figure 13a).

As can be seen from these figures, the system of QR codes with more than 3 holes is already redundant for pipe issues. Expansion of possibilities complicates understanding of QR codes. It is better to focus on periodic repetition of the simple codes with one or two bar elements or one or two holes after natural artifact of the line.

Since, there are no standards requiring pipe-by-pipe coding, a planner can develop own numeration systems. He can choose one of four listed QR code systems taking into account the peculiarities of expected construction or reconstruction.



a

b

c

Fig. 13. Code plate: a) – with one (10) open hole from 30 possible and 7 possible notches on periphery; b – with two and c) – with three open holes
Rys. 13. Tabliczka znamionowa: a) - z jednym (10) otworem otwartym z możliwych trzydziestu i jednym wycięciem na obwodzie z siedmiu możliwych; b - z dwoma i c) - z trzema otworami

The simplest (Figure 13a) method providing sufficient information assumes opening every time of one different diameter hole and application of number of notches on plate periphery. Figure 13a shows two possible diameters and seven notches in code plate upper periphery. The side notches, amount of which corresponds to number of pipeline section, are the auxiliary informative peculiarities and can be used for additional coding of large number of pipes.

The pipe-by-pipe marking is important for underground as well as underwater pipelines, particularly in zones of not stable soil, including tectonic fractions, mountainous terrain, where stressed state of pipeline should be monitored. The environment determines a numbering method (codes) for periodic inspection and observation of separate pipes.

Accuracy requirements to underground pipeline marking systems will increase with rise of operation culture. The pipe-by-pipe marking will facilitate solution of disputable situations that arise periodically in underground pipelines during long period of their operation. Currently, different types of diagnostics are used for this (Figures 1-3). Thus, it is possible to provide monitoring of every pipe that was or should be repaired. All defects, which were found by in-line flaw detector, can be marked on route surface without line opening. The defectograms shows the codes and pipe defects, which should be brought to line surface. Thus, the principle of repair sequence according to defect hazard level (red, orange, gray) can be realized. The color on a route surface determines activities in relation to this pipe with defect.

The pipe coding system, outlined in the technical documentation, will reduce operating costs, time of maintenance and monitoring of individual pipes, and their repair, will promote reduction volumes of excavation work.

Sufficient simplified informative coding can be received using only two or three holes, two or three bar code elements. Pipes deviating from the norm should be periodically monitored by various means of non-destructive testing by means of point test boring without damaging adjacent zones of the pipeline. The exact location of the defect on specific pipe can be easily found on its defectogram and brought to the surface together with its number. The number is easily read by inspectors. Bar or QR code is read by devices and specialists, acknowledged with the technical documentation and conversion tables. Inspectors, diagnosticians and other personnel monitoring the route surface should clearly understand pipe numbers and level (color) of defect hazard. Thus, one of the main information differences in operation of underground and ground lines will be removed. The level of their damaging will be reduced because of decrease of excavation volumes.

According to data of [14], the largest portion of accidents (69%) in underground pipelines is related with external mechanical effect. 26.1% of accidents in the USA are caused by machines and mechanisms. Mechanical loads are created by unauthorized inserts. Complex automatic systems of quick preventive actions are developed to reduce this effect. Any type of quick reaction can be performed only at precise indication of a place of unusual sounds (noise from the mechanisms used for notches).

Everything that is located along the route should be used to bring pipe-by-pipe marking to the surface. These are pickets, measuring points, kilometer and intermediate posts, milestones, external communications crossing the route, including power lines, etc. Pipe markings (red, orange, gray) for defects of various hazards are of particular importance. Underground as well as ground pipes should be "identifiable" without excavations, they should have easy access. Any excavation, any trail boring is a trauma for pipeline, which should be minimized. The principle of "do no harm" will be realized only if the whole lifetime history of each pipe, its diagnostics, repairs, previous trail boring etc are taken into account during excavation.

In-line diagnostics [15] sometimes detects up to 150 - 200 defects per 1 km in certain oil product pipelines, corrosion depth of which reaches 60% of wall thickness of the pipe, regardless electrochemical protection. It is impossible to repair everything and at once. It is necessary to examine amount of defects in one pipe and determine complementary reasons for stress concentration in addition to thinning. There are a lot of such reasons. Therefore, it is impossible to find two identical pipes in one pipeline after long-term operation, repairs, various loads and effect of environment. All of them are different and require different preventive works. Possibility of operation without repair or sequence of repair can't be determined without individual records for each pipe.

Conventional signs (Figure 14) from small pieces of strip (~ 10´20´5) or pipe metal, described in technical documentation, can indicate pipe peculiarities, which were determined in process of construction (reconstruction) of pipeline to the diagnosticians. These conventional signs, located in pipe body, can refer to mechanical damages of different origin, indicate the places of allowable defects, being left without repairs, zones being repaired by welding-up or other technology. The conventional signs of administrative nature can indicate work performer, repair reasons, date and other information. They can have decisive effect of determination on level of pipe risk and stating repair order.

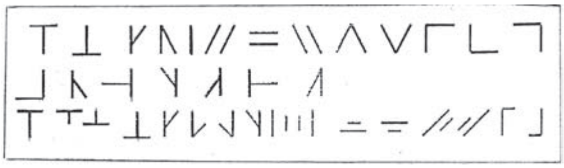


Fig. 14. Signs of technological peculiarities of reconstruction: remained defects, places of welding-up, repair, mechanical damages

Rys. 14. Oznaki cech technologicznych rekonstrukcji: pozostałe wady, miejsca spawania, naprawy, uszkodzenia mechaniczne

Construction organizations, which could master pipe coding and number them along the route, will be more popular than other. The authority of the inspectors indicating the number (code) of the problem tube in their reports will increase. Operators will learn how to mark the problem pipe categories and determine repair sequence without excavation using the defectorgrams of in-line flaw detector. Reduction of excavation volumes and mechanical effects will increase reliability and service life of underground pipelines. It is necessary to monitor every pipe taking into account its origin, life history, repairs and diagnostics in course of many decades. Only such an approach will ensure "longevity" of the whole pipeline.

2. Conclusions:

1) Natural allowable in manufacture and acquired in process of operation defects make all underground pipes different with various level of risk. Risk increases with age (degradation). Therefore, technical state, consideration of the results of repairs and diagnostics, strength calculations, planning of working capacity maintenance should be taken into account for each pipe, not by kilometers, i.e. specifically and individually. Thus, all pipes (sections) should have own numbers (codes), which can be read by in-line and manual flaw detectors.
2) Three-level used in the world practice color ranking of defective zones danger, which comes from grey to orange and red without repair and special measures, should be used for indication of different defects, number of which can be more than hundred per 1 km, and determination of sequence of repairs.
3) Numbers (codes) of pipe, location of ranked defective zones, their color location (risk) should be brought to the line surface, that facilitate their monitoring without test trials and excavations, i.e. as in the case with ground pipelines.
4) Combination of two-three bar code elements or combination of two-three holes on code plate located in pipe body under insulation in specific place, for example, near-weld zone at intersection of assembly circumferential and longitudinal welds, are enough for coding (numeration) of pipes (sections), which can be read in-line as well as manual flaw detection.
5) Ranking of defective zones requires the next sequence. Marking of defects is made without risk evaluation shortly after decoding of diagnostic defectograms. This provides a general pattern of defective zone location on the line surface. Further, risk level (color) and sequence of repair are determined after investigation of information on each defective pipe, performance of strength and expert calculations taking into account weight coefficients considering defect size and other peculiarities. Ranking of the defective zones without repair should be specified with time since risk level rises with age.

3. References/Literatura

[1] Abakumov A.A, Abakumov A.A. (ML). Magnetic diagnostics of gas pipelines. - Moscow: Energoatomizdat, 2001, 440 p.
[2] Paton B.E., Troitskiy V.A. The main areas of work of E.O.Paton Electric Welding Institute in improvement of non-destructive testing of welded joints. - Proceedings of the 8th National Conference UkrNDT-2016, p. 8-28.
[3] Tsykh V.S, Yavorsky A.V. Electromagnetic testing of isolation of underground pipelines from land surface. - Proceedings of the 8th National Conference UkrNDT-2016, p. 206-207.
[4] Dzhala R.M., Verbenets B.Ya., Melnyk M.I. New methods of testing of PKZ of underground pipelines by currents and potentials measurement. - Proceedings of the 8th National Conference UkrNDT-2016, p. 236-239.
[5] Dubov A.A, Magnetometric diagnostics of underground pipelines. www.energodiagnostika.ru.
[6] Construction of main pipelines. Reference book. Chirskov V.G., Berezin L.G. et. al. - M. Nadra, 1991. - 475 p.
[7] Non-destructive testing edited by Kluev V.V. Reference book in 8 volumes, 2010. Book I. Moscow, "Spectrum"
[8] Troitskiy V.A. Magnetic particle testing of welded joints and machine parts. K., 2002, "Phoenix", 300 p.
[9] A.S .No. 1214984, MPK8: F17D3 / 00, published 28.02.86.
[10] Patent of the Russian Federation No. 2511787, MPK9: F17D5 / 02, published April 10, 2014
[11] Kovalenko A.N. Systems for determination of location of pipeline defects. Testing and diagnostics, № 2, 2016, p. 27-35.
[12] But V.S., Oliynyk O.I. Strategy of development of technologies for repair of operating main pipelines. Collection of papers on "Problems of the resource and safety of operation of structures, constructions and machines" for 2004-2006, Resource, p. 490-500.
[13] Sarazha S.V. Implementation of the new concept of diagnostics of technological pipelines at OJSC "Samotlorneftegaz". "Territory of NDT", No. 4, 2013, p. 36-41.
[14] Galiulin R.V., Bashkin V.N., Galiulina R.A. The problem of non-sanctioned inserts in liquid hydrocarbon pipelines. Journal of Oil and Gas Construction. 2013, No. 4, p. 46 - 49.
[15] Galyautdinov A.A., Zubailov G.I. To the question on pipelines dismantling. Oil and gas business. 2007. http: www.ogbus.ru.