THE IMPORTANCE OF MAINTAINING VALVE RECORDS

Chas. W. Gibbs* and K. H. White
Ingersoll-Rand Co.

Operators of synthetic ammonia and air separation plants have, quite rightly, included discussions of valve failures in at least the last two symposiums. Valve failures can cause overheating, some unbalance of compressor interstage conditions, and compressor shutdown, requiring subsequent restart. Overheating has overtones of danger, particularly when air is being handled. Compressor internal unbalance can at times cause concern, but shutdown and subsequent restart result in disturbance of operation throughout the plant, a condition conducive to accidents. The fewer the valve failures, the greater the safety of operation.

The service required of a valve in the modern process compressor is extremely severe, the severity being seldom fully appreciated. In an average process compressor in air and ammonia plants, each valve must open and close nearly 500,000 (1/2 million) times every 24 hours. Considering the temperatures, pressures and gas conditions under which many valves operate, everyone must concede that modern valves do a good job. But no one is satisfied—least of all the manufacturers. Efforts are being made continuously to improve valve life. This report will discuss only reciprocating compressors.

Valve failure and remedies

Valve failures can be pretty well classified as resulting from three general causes:-

1. Wear and fatigue.
2. Foreign materials.
3. Abnormal mechanical action.

Before discussing any of these, it must be pointed out that the final design of any piece of equipment entails some compromises. It is practically never possible to build even as small a part as a valve assembly in the optimum design for any given job.

Wear and fatigue

WEAR, as such, cannot be 100% eliminated. It can be minimized by proper lubrication, design, and selection of materials.

Most valves require some means of guiding. Wear at the guides—if severe—can result in sloppy action, cocking, poor seating and failure. Wear should not be permitted to develop to this point.

FATIGUE is the result of repeated cyclic ~~stres~~ stress. The stress level as well as the stress range must be considered in any design. However, barring abnormal action, well designed valves give a good account of themselves as far as fatigue is concerned.

Abnormal conditions can and do increase the effect of both wear and fatigue adversely.

Foreign Materials

These can be listed in the following categories.

1. Liquid carryover.
2. Dirty gas.
3. Carbon formation.
4. Corrosive elements.

LIQUID CARRYOVER from a process or from interstage coolers is apt to cause premature failure, particularly on intake valves. A slug is particularly hard on valves and may even break a seat. Liquid also destroys lubrication, accelerating wear.

Carryover can result from poor separation of condensate ahead of the compressor, or improperly designed piping where low spots permit accumulation. A sudden flow change can then cause a carryover.

It is important that interstage separators be drained regularly and we are of the opinion that manual drainage at specified intervals with the fact of drainage logged, is the proper method, particularly at the higher levels. Automatic traps, if used, should have a bypass piped for visual observation and check on trap operation—the check to be made at stated intervals and the results logged.

Examination of the valve plate will sometimes indicate liquid carryover or momentary high pressure damage, but liquid in a cylinder is generally discernible otherwise.

DIRTY GAS can cause all sorts of problems. It accelerates wear very rapidly at all guiding points since it is usually a good grinding compound. Foreign matter between the coils of springs is a frequent cause of spring failure and subsequent failure of other parts.

CARBON—proper valve action may be hindered by carbon or sludge resulting from an unfortunate combination of a particular oil and the gas being pumped. The additives in an oil in combination with a certain gas can sometimes result in trouble. Such a thing as this is unpredictable but, in some cases, simply trying another oil has been successful. Too much oil can be as undesirable as too little oil. The rate of feed must be determined from experience and should be no more than is necessary to lubricate a cylinder properly.

CORROSION can cause high localized stress and subsequent failure. Springs are apt to fail first. The solution to corrosion problems is not always simple, and is rarely inexpensive. Valve materials can be changed. In some cases, scrubbers or chemical washes can eliminate or reduce contaminants before they enter the compressor. In a few cases simply increasing jacket water temperature or preheating the gas has eliminated condensing-out of corrosive elements.

Corrosion may not cause valve failure for several months. When it does, it is best to change out and repair all the remaining valves, because they are probably close to failure. When there is a corrosive condition that cannot be eliminated, it is best to have a complete set of spare valves. This will result in less down time and less final expense.

As a corollary note—when sending a valve with suspected corrosion failure to the manufacturer for examination, send the valve exactly as removed from the cylinder—neither disassembled nor cleaned up. Also send a sample of deposits from the cylinder passages. Pack it in a sealed bag as rapidly as possible to prevent any change due to oxidation of deposits.

*Retired

Abnormal mechanical action

In this category, detective work is sometimes necessary. There are four general causes of abnormal operation, although there is some inter-relation between them.

1. Slamming.
2. Fluttering.
3. Resonance or Pulsation.
4. Flow Pattern.

SLAMMING can occur when a valve opens or when it closes. We have seen that valves normally have little tendency to slam except possibly when the discharge valve is opening.

Valve opening can be cushioned either mechanically (by springs) or by a gas cushion—or by both.

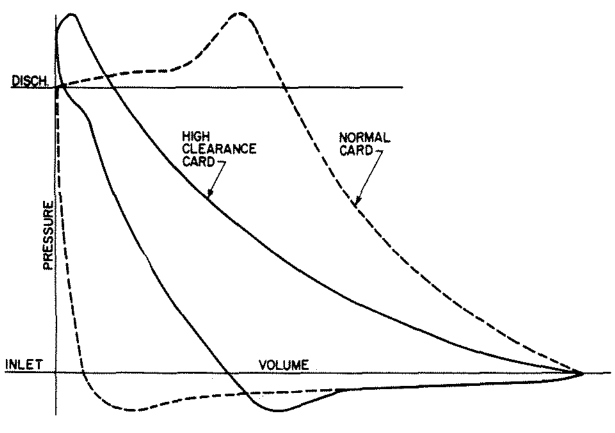
If a valve should close late, whatever the reason, backwash air flow rather than the springs will close the valve and slamming is certain to occur. Slamming is suspected if the plate has a hammered or mottled appearance where it contacts the seat. Listening will often confirm slamming.

Clearance pockets, used to give partial unloading, sometimes cause slamming of discharge valves. Figure 1 will illustrate what happens. When clearance is added to a cylinder, the discharge takes place later in the stroke. Of course, with enough clearance, there should be no gas discharged at all.

Any valve requires a finite time to open or close due to its inertia. If the clearance is such that the valve is opening near the end of the stroke, it may happen that inertia of the valve is carrying it open even after it should be closing. Backflow, after dead center is reached will then slam the valve shut and eventually cause it to fail.

This type of slamming failure can usually be eliminated by decreasing the lift and/or using stiffer springs to change the valve timing and assure that the valve is closed at the end of the stroke.

FLUTTERING is a result of insufficient pressure drop through the valve. The pressure drop is a function of velocity, density and flow coefficient. If springs are too stiff, a valve may be unable to fully open and instead of being held securely against its stop it remains somewhere between zero and full lift and oscillates. Springs usually suffer under these conditions. In severe cases a valve may strike the seat or stop plate several times during one stroke of the piston. The inertia of the valve may cause it to open



EFFECT OF HIGH CLEARANCE
FIGURE 1

fully against its stop but pressure drop may be insufficient to hold it there—consequently, it starts to close again. Inertia may close it too far, even back to the seat before flow forces start it opening again. By the end of the piston stroke it may have oscillated several times. Furthermore, at the end of the stroke inertia may be carrying the valve open instead of back toward the seat and when backwash finally closes the valve it is with a slam.

Examination of the valve and seat may confirm fluttering. If the stop plate shows no markings it may indicate that the valve has not fully opened. Normally the back of the valve plate itself will have some sort of pattern from the springs. In a circular or plate valve, if there is no definite pattern, and the plate appears to spin, then fluttering is a likely cause of failure.

The solution to a fluttering valve is to lower the lift and/or to use lighter springs.

RESONANCE OR PULSATIONS—normal valve action can be upset by pulsations. The amplitude of pulsation is of considerable less consequence than the phase relation of the pressure valve and crank angle. A pulsation can cause late closing, thus slamming as previously mentioned.

Figure 2 diagrams on a time basis what happens. The valve is not only open at dead center but the rate of pressure change is high. The valve is slammed shut by backflow after dead center.

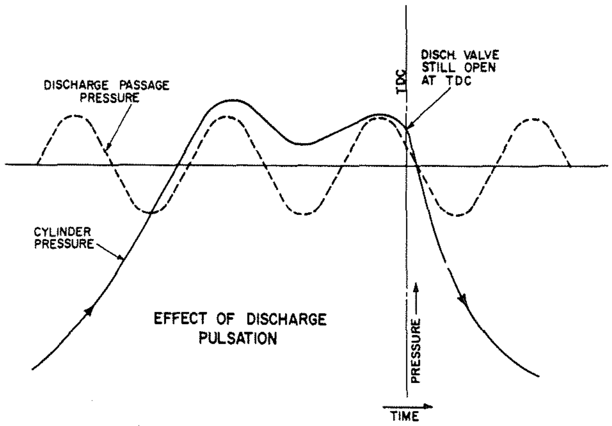


FIGURE 2

The basic solution to this problem is the elimination of the pulsation through piping changes. Sometimes the installation of an orifice will do the trick. This is a case where the problem is completely outside the valve designer's control.

FLOW PATTERN failures are few and far between but we cite them because they have happened. There may be a disturbance within the cylinder passage leading to a valve which causes some type of erratic valve action.

The cure is to change the lift and/or springing (depending upon the type of failure) or even to change the valve type. The basic cause may not be immediately discovered, but when it is, steps can be taken to improve the flow pattern itself in subsequent cylinders. In any case, we can eventually obtain normal life.

Valve records and case histories

So far we haven't even mentioned valve records, but the problems in the following case histories were solved only after accurate records had been kept.

CASE 1

First reports were that all valves were failing in all stages. No records were kept in the beginning. After records were kept and analyzed it was evident that troubles were mostly discharge valves. Careful checking indicated heavy carbon deposits resulted in fouling of valve action and subsequent failures. Changing to different oil cleared up the troubles. In some cases valve failures in one stage caused trouble in the next higher stage because of small pieces being carried over.

However, the troubles on this job were not all due to carbon buildup. Records showed where to concentrate efforts and when the major problems were cured the minor problems took care of themselves. In some cases discharge valve failures occur from broken pieces of inlet valve which carry over. Curing inlet troubles thus solves discharge troubles.

CASE 2

Inlet valves failed. Examination of parts indicated good valve action, no fluttering. The type of failure indicated liquid carryover from process. Customer doubted it. Troubles were mostly in the summer and rarely in the winter. It was finally discovered that inlet gas temperature in summer was actually lower than in winter because intake pipe was steam traced in winter. In summer the steam was turned off.

Intake temperature of gas was increased about 20 degrees during the summer, and troubles ceased. Failure occurred because of condensate in intake pipe and because wet gas formed acids which attacked valve parts. The discharge valves, which run hotter, were not attacked. Also, discharge valves normally do not fail due to liquid slugs in cylinder. Records of intake temperature gave the clue to solving this job.

CASE 3

Records of valve troubles clearly pointed out that failures were confined to outer end discharge valves only. The outer end had a clearance ring under the head to give added clearance. The added clearance was thus suspected as being the reason for trouble.

When the clearance ring was later removed because of changing conditions, failures disappeared.

On other jobs we have had discharge valve failures when the outer head clearance pocket was open but not when closed. It is important to have records which verify that the opening of the pocket and failure went hand-in-hand.

Failures usually can be eliminated when the pocket is open by decreasing lift and/or using stiffer springs to make certain the valve is being closed at the end of the stroke.

CASE 4

Reported valve troubles were finally boiled down to discharge only. There were no clearance pockets involved and ratio was such that late closing of discharge valve was eliminated as a factor. Returned parts showed some corrosion. Material was changed but did not help much. It was later reported that valves ran three months—then two failures occurred within a couple of days. Customer's records indicated discharge pressure was not constant and troubles seemed to occur above a certain pressure, but not below. Further quizzing of customer indicated discharge pipe vibration when this value of discharge pressure was approached.

An analog computer verified a resonant condition at this point and an orifice was installed. Pulsations were eliminated and valve troubles ceased.

CASE 5

This was a pulsation problem.

Trouble was confined to outer end discharge valve only on third stage cylinder. In this case we installed a new style valve which cleared up the trouble. A pulsation bottle helped but did not originally cure the trouble.

CASE 6

After considerable inlet valve trouble, records finally indicated that only two of the four inlet valves per cylinder end were failing. The two inlet valves next to the horizontal centerline of the cylinder were in trouble, but not the other two. This indicated that there was something peculiar to this cylinder which resulted in the failures. Examination of the valve parts showed that the valve did not fully open and was evidently fluttering. The trouble was eliminated by putting in lighter springs which permitted the valve to fully open without fluttering.

A few months later we got a report of identical trouble at another plant. It turned out that the same cylinder was used on this job and the same valves failed. Trouble was again corrected in the same manner. Incidentally, when we went to lighter springs we changed all inlet valves in order to prevent confusion.

The cylinder passage ribbing apparently resulted in a flow disturbance or pressure drop ahead of two of the valves and this resulted in fluttering. A redesign of the cylinder was the ultimate answer. Here again, pinpointing the trouble by keeping good records resulted in the solution.

Typical valve record systems

One of your authors visited a number of synthetic ammonia plants a few months ago and had an exceptional opportunity to review record systems. If the plants we called on provided a good cross-section, then most valve record systems are of the somewhat informal "little black book" type. The information is there, but it is not generally tabulated or charted. Valve failures may actually be occurring that could be reduced in frequency, but the possibility may not be recognized.

It has been our experience that a systematic study of valve problems is necessary for the best results. We feel that records should be more elaborate than just showing where failures occur. A picture of some sort is required.

How far one goes into this is to some degree dependent upon the number of machines and valves involved. A plant with one or two machines and maybe 50 to 70 valves may use a simpler system than a plant with six to eight units and 500 to 600 valves.

The type of maintenance also plays a part in the need for elaborate valve records. It is our opinion that those of you with some type of pool maintenance, where there are several individuals involved in valve repair, will find good records of greater value.

We have permission to show in this paper two adequate records systems. One is just the ultimate—the other wholly adequate. We will show examples only—not necessarily the charts for every unit in a plant. We will discuss the minimal plan first.

This plant has five trains, four of which are substantial duplicates. Fig. 3 shows the record for the principal cylinders (as far as valves are concerned) on one train.

PRIMARY COMPRESSOR VALVE NUMBERING SYSTEM

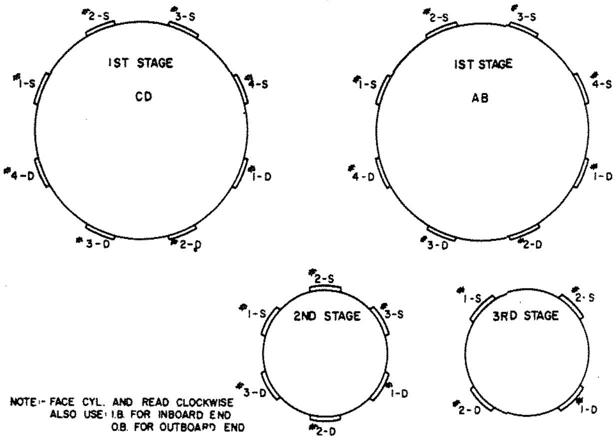


FIGURE 3

The other cylinders on this train had only one inlet and one discharge valve per cylinder end and a log on plain paper fastened to the other form was used for valve changes in these cylinders and for other logged items of maintenance.

In one case, this chart had entries for more than five years. It was quite clear that there had been more trouble in the early years than in recent times. The influence of cooperative work between the plant personnel and the manufacturer was clearly shown. Adequate records show trends.

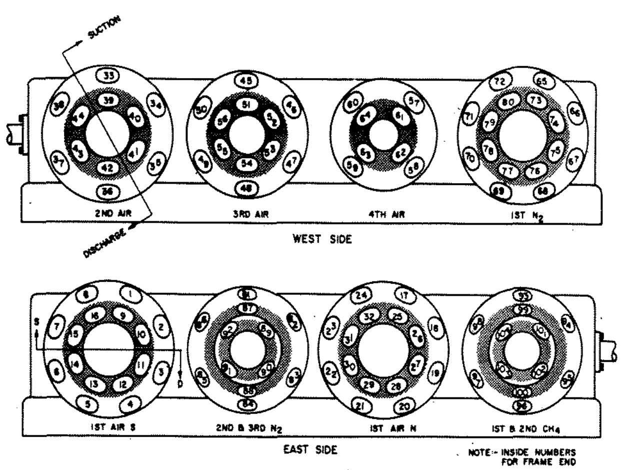
No record is kept in this plant as to causes of specific failures. The valve is examined by the operating personnel after it is removed by maintenance and they satisfy themselves as to the cause and take appropriate steps if they feel it is warranted.

Complex system

The other plant is much more complex. Records here are kept in considerable detail. Again, we will discuss in the main only a typical unit.

The plant consists of eight units of three different types. The units are known as:-

C- 101-A-B-C
C- 104-A-B-C
C- 105-A-B



C-101 MULTI-GAS COMPRESSOR
VALVE LOCATIONS

FIGURE 4

Every valve location is numbered consecutively, starting with unit C-101 and up through unit C-105. A letter is added for the particular A, B or C unit, thus identifying exactly a given valve location. Fig. 4 is the valve number chart for the multiple gas units. The outside numbers are for the outboard end and the inside numbers for the inboard end.

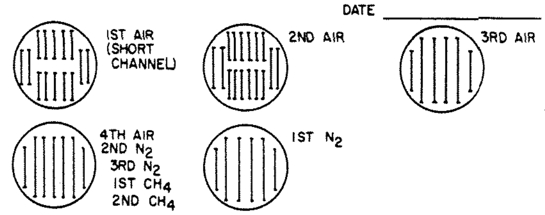
When a valve has to be changed, the shift mechanic removes the valve and installs a reconditioned valve immediately. The valve which failed is then examined by the chief operator and the shift supervisor who fill out the report shown in Fig. 5.

This identifies valve location and tabulates items to be checked off to show what failed. Note that cylinder lubrication is also checked while the cylinder is open.

VALVE CHECK LIST

C-101

DATE ____________



USE (X) TO DENOTE LOCATION OF CHANNEL AND/OR SPRING FAILURE

COMPRESSORS: C-101 A B C

VALVE NUMBER: ____________

GASKET CONDITION	LEAKING [ ]	BROKEN [X]	GOOD [X]	REPLACED [ ]
VALVE CONDITION	CLEAN [ ]	DIRTY [ ]	LOOSE SCREW [ ]	BROKEN CHANNEL [X]
	WEAK SPRING [ ]	BROKEN SPRING [X]	COCKED [ ]	
CRAB CONDITION	GOOD [ ]	LOOSE [ ]	CRACKED [ ]	
OIL ON SIDE OF CYLINDER	SUF-FICIENT [X]	DRY [ ]	WET [ ]	
OIL ON BOTTOM OF CYLINDER	SUF-FICIENT [X]	DRY [X]	WET [ ]	

TIME DOWN: FROM ____________ TO ____________

REMARKS: ____________

CHIEF OPERATOR ____________

SHIFT ____________

FIGURE 5

This report goes to headquarters where a chart log is kept which shows when, where, and what failed. The chart classifies type of failure by a number, as follows:

1. Gasket failure
2. Spring failure
3. Channel failure
4. General failure
5. Foreign material
6. No failure
7. Cocked
8. Crab failure

An entry of a letter for the machine and a number for the type of failure under a valve location number tells the whole story. A portion of one of these 11" × 17" charts is reproduced in Fig. 6 with entries as on the plant's 1959 chart.

Note that, for the two cylinders shown, unit A had more valve changes than B or C. But, notice that they were all on one day and that five changes indicated no valve failure. In other words, these changes were unnecessary.

There is a further yearly summary of types of failure designed to show when certain parts are failing too often and also to spot poor maintenance (such as

	FOURTH STAGE AIR C-101								FIRST STAGE N_2 C-101 A,B,C															
DATE	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
2-16-59															B2									
3-25-59																			B8					
5-18-59				C3																				
5-29-59				C6		C6												C2						
7-30-59		A1	A1	A6		A1	A1			A6		A6			A6			A2					A6	

FIGURE 6

cocked valves) or poor judgment in deciding on a shutdown.

We asked many people in many plants recently what they considered the most important factors in obtaining best valve life. The following list gives the answers in approximate order of frequency.

1. A limited number of well-trained men on valve overhaul.
2. Clean gas.
3. No liquid carryover.
4. Proper lubrication.
5. Systematic records.
6. Best materials.

The unanimity of opinion with regard to the first three items was remarkable.

Questions

HEPP: We had a little experience with valve failure somewhat differently than any of the failures you mentioned here. I'd like your comment on it. After running for a year or a year and a half without too much difficulty, we ran into a rash of valve failures, and eventually traced them to the fact that good valves that are removed at a valve change were being reprocessed and re-lapped, and eventually, after several relappings, were getting down too thin and failing due just to the fact that the valve was too thin. I just wondered what your comments were on this practice of lapping valves?

C. W. GIBBS - Ingersoll-Rand Co.: I would say—don't do it too much, because a valve is a relatively inexpensive piece of metal compared to a shutdown or a changeout. We set minimum thicknesses for valve plates in our instruction books to try to eliminate the problem you encountered.

STOCKBRIDGE: Mr. Gibbs, I wonder if you might be able to enlighten me as to why liquid is so bad on valves?

GIBBS: One of the reasons is that it helps destroy lubrication. I've seen valves that have been handling liquid ammonia where the separation was inadequate ahead of the compressor. I've seen those valves cut as if you'd taken a file and cut across them. You want to keep all the liquid out of a compressor cylinder you can; it not only damages valves, but it wears out liners, rings, and packing.