Compressor Suction Accumulator with Pre-Charged Oil

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ABSTRACT
A compressor accumulator based on a different concept from a conventional suction accumulator is proposed. The new accumulator distinguishes itself from the conventional design in that it is pre-charged with oil. Primary function of an accumulator being storage of excess refrigerant during certain operating conditions of the air conditioning system, this pre-charging may first seems odd, but from a compressor reliability standpoint it offers several major advantages compared to the conventional accumulator. An example of such an accumulator is introduced, operational characteristics observed, reliability evaluated and potential risks defined.

INTRODUCTION
The primary function of a suction accumulator in rotary compressor is to control excess liquid refrigerant. However, the accumulator is normally limited in size for reasons of cost, space available, or as a matter of design choice. This limitation allows only a certain maximum oil/refrigerant ratio where the amount of oil is determined by the size of compressor oil sump and the amount of refrigerant is set by the charge amount which optimizes system performance. Therefore, increasing the ratio to the advantage for compressor reliability is not readily possible in most cases, without a major redesigning of compressor and/or air conditioning system. A concept which improves the oil/refrigerant ratio by having an accumulator with pre-charged oil is introduced in this paper. Basically, the concept involves an accumulator pre-charged with oil that is retained in the accumulator. As liquid refrigerant enters the accumulator, it mixes first with oil in the accumulator and improves the quality of oil/refrigerant mixture before entering compression chamber of rotary compressor. This is a unique new concept (Fig. 1) of designing an accumulator compared to the conventional (Fig. 2) accumulator known to date. The concept has been under development and proven its feasibility with significant potentials. Reliability tests with extreme refrigerant overcharge have demonstrated advantages of the accumulator of this new concept. Behavior of excess liquid refrigerant in accumulator and compressor oil sump demonstrates why this new concept is advantageous in minimizing negative impact of excess refrigerant.
FUNCTION OF A SUCTION ACCUMULATOR

Suction accumulator is a multi-function component in a compressor, including suction muffling, filtering of contaminants. The prime function of an accumulator, however, is storing excess liquid refrigerant prior to entering compression chamber of compressor. Since refrigerant flow always contains refrigerating oil, oil is also collected in accumulator as refrigerant/oil mixture enters the accumulator chamber. To insure oil return to compressor, a provision must be provided to return the collected oil from the accumulator. The oil return is accomplished by an orifice located on the bottom portion of standpipe or “hockey stick” as some call it. Refrigerant/oil mixture is drawn into compressor suction through the orifice by Venturi effect.

THE PROPOSED CONCEPT

The new concept concerns with compressor and accumulator for air conditioning and refrigeration compressor. Particularly, the suction accumulator is pre-charged with refrigerant oil that is contained ordinarily in accumulator body. This pre-charged oil amount is in addition to the amount of oil normally charged into compressor oil sump, and makes the total amount of oil charge greater. This increased oil helps improve compressor lubrication under boundary lubrication condition due to liquid refrigerant. Without increasing oil amount in oil sump, the quality of the oil is improved with an accumulator with pre-charged oil. That is, additional oil is charged into the accumulator, and oil return orifice is so located in elevation that a specified volume is contained below the orifice. In reality though, the volume does not necessarily contain pure because suction vapor contains refrigerant all the time.

Though the pre-charged oil may partially leave the accumulator when liquid refrigerant contained in the accumulator raises level of liquid phase above orifice on standpipe, the pre-charged oil is mainly contained in the accumulator. This type of accumulator (Fig. 3) offers a significant advantage under flood-back condition of liquid refrigerant. The liquid refrigerant flowing into the accumulator first mixes with oil contained in the accumulator prior to entering compressor suction intake. This mixing of liquid refrigerant and oil improves the quality (oil/refrigerant ratio) prior to entering compression chamber, thus making quality of lubricating oil in the compressor oil sump. Additionally, the amount of oil pre-charged increases the total amount of oil in the system without the necessity of making the oil sump larger.

IMPACT TO ACCUMULATOR EFFECTIVE VOLUME

Obviously the oil reservoir takes a chunk of volume out of the accumulator. This may not be an issue if the accumulator volume is sufficiently large to start with. If a large diameter of accumulator is not an option, there is a way to get around the situation. Because of the desired low elevation of oil reservoir, to maintain a certain minimum effective volume of accumulator, a proposal here is to extend accumulator downward beyond the ordinary accumulator elevation. Figure 1 and 3 illustrate the proposed design which compares to the conventional (Fig. 2 and 4). What this does is to increase the accumulator volume in a great extent.
OIL/REFRIGERANT RATIO

Protecting compressor from a lubrication failure is an age-old challenge to compressor engineers. Even a well designed bearing of optimum dimension, material and manufacturing do not necessarily guarantee reliability of a bearing. In an air conditioning system, the oil/refrigerant ratio plays a critical role in this regard. For this reason, compressor manufacturers recommend minimum limits for value of this ratio for compressor protection. The oil viscosity, a determinant for lubrication, is determined by the proportion refrigerant dissolved in the oil/refrigerant mixture and the pressure the mixture is exposed to. Thus, in order to maintain the minimum viscosity required for a certain bearing design, derived from the minimum film thickness requirement, the oil/refrigerant ratio needs to be kept at a reasonably high level. In certain air conditioning system the ratio may not meet the minimum recommended level. In this case, countermeasures are normally expensive, it they are feasible. To help solve this type of situation, an accumulator with pre-charged oil can be used.

Obviously, higher the ratio, better the lubricant oil quality. However, the quantity of oil is determined by the amount of oil charged in the compressor factory, plus any additional amount added to compensate a long-line situation in split system or oil loss during system leak situation. On the other hand, refrigerant amount is normally determined at the factory while additional charge is added to compensate a long-line situation or during servicing the system. It is generally known in the field that service technicians tend to add additional charge on the belief 'the more the better.' If refrigerant charging in the field involves charging by suction superheat or even by amperage draw a substantial over-charging may results.

As the ratio is a relative number, it can be improved either by increasing oil amount and/or reducing refrigerant amount. However, the difficulty lies in the fact that, in actuality, neither of these two options are not readily available options. First of all, increasing oil amount normally requires compressor shell change to accommodate more oil in oil sump. This approach could mean change in shell tooling at a substantial capital expenditure, or additional oil charging which could result in increased oil circulation rate. This may not be an acceptable option. Secondly, the refrigerant amount is determined from system matching test, and the pre-determined charge amount is for optimum system performance. Therefore, it is not wise to reduce the charge from the recommended amount. If anything, the amount tends to be more on overcharged side rather the undercharged in serviced systems.

BEHAVIOR OF THE NEW ACCUMULATOR

We can examine the behavior of the proposed accumulator under several operating conditions; dry suction flow, liquid refrigerant and somewhere between condition on a continuum.

(1) DRY SUCTION - If the suction flow is superheated to the extent to insure dryness of the suction vapor, no liquid-phase refrigerant accumulate in the accumulator. Thus, liquid below the orifice is oil-rich mixture or mainly oil. In this case, the accumulator in fact acts as an oil reservoir. In this case, any shot of in-rush liquid refrigerant mixes with the oil in the accumulator prior to entering the compression chamber. The quality of the suction flow is relatively more oil-rich compared to the ordinary accumulator where no oil is pre-charged, i.e., accumulator without a reservoir.
(2) **WET SUCTION** - As suction superheat decreased more liquid droplets present in the stream and the quality of the suction becomes "wet" meaning more refrigerant-rich flow. Circulating oil is mixed in the vapor flow and the oil sump in the accumulator now mixes with more refrigerant. As this happens, the relatively small amount of liquid mixes with oil in the reservoir, making the suction quality more oil rich compared to the case of dry suction above. The liquid level in the reservoir becomes more agitated.

(3) **LIQUID FLOOD-BACK** - As another extreme condition, now liquid-phase refrigerant rushes into the accumulator. The liquid-phase level of the reservoir is raised and becomes further agitated and foamy. Though the quality of suction flow depends on relative amount of the oil and liquid-refrigerant flow, it has better quality than the case of the ordinary accumulator design that does not contain oil in any measurable quantity. The liquid refrigerant after being diluted with oil enters the compression chamber of compressor.

**RELIABILITY EVALUATION**

The proposed concept being non-conventional compared to the conventional accumulator as known today, reliability is one of the prime interests. Development samples were built and tested at various operating conditions. Among various evaluation tests, including continuous run conditions (at high load, high pressure differential, high compression ratio); on/off cycling, blocked fan, liquid flood-back and transient slug tests, special attention was given to tests involving suction flood-back and transient slugging of liquid refrigerant. The concept offers a substantial advantages in dealing with excess refrigerant and liquid flood-back. Compressors equipped with the oil reservoir have lasted longer in life under severe suction flood-back and transient liquid flood-back conditions.

A failure mode and effect analysis (FMEA) shows, however, a potential reliability risk if the reservoir is not charged initially with oil. In this case, the empty reservoir can rob oil out of compressor oil sump. Similar risk arises when system loses oil by refrigerant leakage. Appropriate countermeasures should be in place in compressor manufacturing process and field service.

**OPERATING CHARACTERISTICS AND INHERENT ADVANTAGES**

The following lists several operating characteristics observed and inherent advantages of the new concept:

1. The accumulator seldom allows the slug of liquid to go directly into compression chamber of the compressor. The reason is that any slug of liquid first mixes with oil in the reservoir, thus it is no longer act as a true slug of liquid when it reaches to the inlet of standpipe.

2. As liquid refrigerant mixes with oil, the resultant liquid/oil mixture is now less damaging to compressor lubrication compared to the case where slug of liquid is directly drawn into the compression chamber. In reality, the oil reservoir acts as a "shock absorber.”

3. In the event that a slug of liquid momentarily displace oil in the reservoir, oil does return to the reservoir at the original level.
4. The oil stored initially in the accumulator reservoir improves the oil/refrigerant ratio. This is true even if the additional oil is located in the accumulator reservoir separately from the compressor oil sump. The oil reservoir contains some refrigerant and additional oil will be drawn into the compressor.

5. In a steady state operating condition, oil-rich liquid level in the accumulator stays at the level of the orifice elevation. Any excess liquid refrigerant/oil is drawn into compressor through the orifice.

6. In the particular size of accumulator cited in the example, the oil/refrigerant ratio of suction vapor improves substantially.

7. Normally increasing the size of compressor oil sump is a capital-intensive and it may even not be feasible due to complexity in manufacturing. In this kind of situation, the concept offers a practical alternative to increasing the oil sump.

**SUMMARY**

From the concept to experimental verification, the proposed accumulator, through development stages, has proven its basic feasibility, performance and reliability. Despite several manufacturing and application challenges remaining, advantages far outweigh potential risks. On this basis, the concept is being further refined for design optimization and manufacturability.
Fig. 1 The Proposed

Fig. 2 Conventional

Fig. 3 The Proposed Accumulator

Fig. 4 Conventional Accumulator